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FOREST SERVICE
F. A. SILCOX, CHIEF

IMPROVEMENT HANDBOOK

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PREPARED BY
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PREFACE

Purpose

The purpose of this handbook is to make available the methods and standards recognized as good practice in building structural improvements on the National Forests to Forest Service engineers, architects, and men engaged in construction.

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CHAPTER XXV

None

CHAPTER I - PRELIMINARY PLANNING FOR BUILDING DEVELOPMENTS

1. Building Development Sites

A. General Considerations

The selection of the building site itself is just as important as the erection of buildings according to approved standards of construction. Whether the building is located in a city or town, or is one of a group at a Ranger's Headquarters or stands alone at the intersection of two trails in the back country, its location must be chosen with extreme care and forethought.

In addition to matters of administration and utility, a site should be chosen with due regard for its geographical and climatic location, in conformity with the functions outlined herein. Under certain conditions where roadside scenic strip rules are in force, allowance must be made for building set-backs from roads.

Where an entirely new building development is contemplated, careful consideration should be given to the location of every building in the scheme or group before deciding upon or procuring the site.

Where new buildings are to be located on partially developed sites, it is essential that well-considered comprehensive plans for the complete future development of such sites be made so that subsequent replacements or additions will conform to the general scheme and result in the general improvement of the entire project. Where sites are restricted to those which have already been partly improved, as mentioned above, it will be found desirable in some instances to abandon them and either scrap or move their existing buildings to an entirely new location.

While, under certain circumstances, the site proposed for a Headquarters' development may be reasonably level in order to facilitate the most efficient arrangement and construction of the contemplated buildings, it will very often be found that sloping ground is more suitable because of other special advantages it may possess.

B. Water Supply

A water supply adequate for domestic purposes is essential. In addition, water for fire protection, lawn sprinkling and irrigation is desirable. Before a site is finally decided upon, the available sources of supply should be carefully investigated. The investigation should include a definite determination of the amount of average flow and the quality of the water itself.

Attention is called to the Forest Service "Small Water Developments Handbook" for assistance in planning water supply and sewage

disposal systems for Forest Service Buildings.

C. Sewage Disposal

In cities and towns, sewage disposal systems should be arranged to conform to local rules and regulations.

In other locations, sites should have sufficient natural drainage and the subsoil should be of such a nature that the satisfactory disposal of sewage is possible. See the Sewage Disposal Chapter of the Small Water Developments Handbook for design details.

D. Light and Power

The possibility of connecting to existing light and power lines or the alternative of providing these facilities as separate installations should be considered in order to permit the use of modern equipment, appliances, etc.

E. Telephone and Radio Service

The immediate availability of a telephone and radio service should not be overlooked in selecting a building site because these services are an integral part of every Forest Service Ranger Station or Office.

F. Natural Advantages

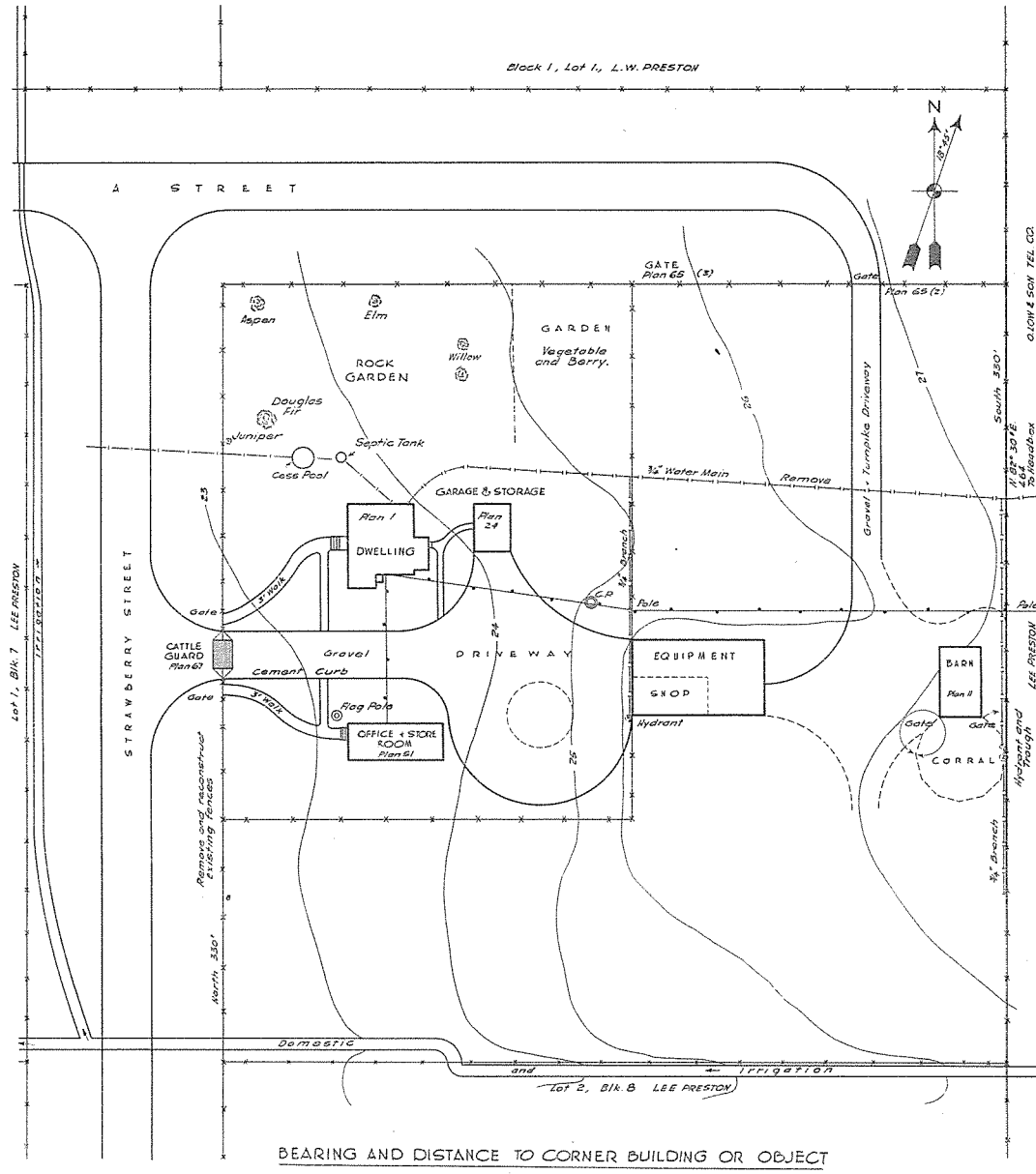
Other factors which influence the choice of site are those of natural setting, topography, exposure, maximum and minimum temperatures, amount of snowfall and rainfall, velocity and direction of prevailing winds, amount of sunlight, trees, shrubs, shade, shelter, fertility of soil, availability of pasturage, highways, railroad sidings, etc. Locations likely to be hazardous from rolling or falling rocks, earth, rock or snow slides, etc., should not be considered.

G. Site Surveys

All development sites should be surveyed to the extent of running the exterior lines. Where a particular site, not already Government property, is being considered for purchase, all ties should be checked and the boundary lines of the site surveyed. Following this it is desirable to establish a so-called "Central Point", at a central position on the site, and mark it by a large rock, a piece of iron pipe driven in the ground, or a metal tablet. From this point, bearings and distances may be run to the nearest corner of each existing structure. The central point should also be tied to existing surveys wherever possible. This information should be recorded on the Map or Improvement Plan for the site.

A convenient method of recording site data is as follows:

(1) Prepare a field map of the proposed site on an Atlas size sheet, 18" x 21", and show the exact location of buildings, fences,



BEARING AND DISTANCE TO CORNER BUILDING OR OBJECT

N. 52° E.	221 Ft. N.E	Lot 1, Blk. 8 Bedford, Wyo.
S. 38° 30' W.	250 Ft. S.W.	Lot 1, Blk. 8 " "
S. 82° 30' W.	148 Ft.	Barn Plan 11 Prop.
S. 46° E.	23 Ft.	N.W. Equipment and shop
S. 49° 30' W.	163 Ft.	N.E. Old Office Storeroom (Moved)
S. 50° 30' W.	81 Ft.	N.E. Office and Storeroom Plan 51
N. 79° W.	76 Ft.	S.E. Dwelling Plan 1
N. 46° 30' W.	35 Ft.	S.E. Garage-Storeroom Plan 51, Prop.
S. 85° W.	155 Ft.	N. End Cattle Guard Plan 67, Prop.
N. 47° W.	128 Ft.	S.E. Old Dwelling (Moved)
N. 24° 30' W.	131 Ft.	S.E. Woodshed (Moved)
N. 1° 30' W.	65 Ft.	S.W. Old Barn Garage (Moved)
N. 16° 30' E.	129 Ft.	S.W. Chicken coop (Moved)
N. 87° 30' E	147 Ft.	S.W. Chicken Coop - New site (Moved)
S. 66° W.	118 Ft.	Flagpole

IMPROVEMENT PLAN OF BEDFORD RANGER STATION, WYOMING NATIONAL FOREST

SAMPLE IMPROVEMENT PLAN

roads, telephone and electric poles or other pertinent features by bearing and distance from the "Central Point". Likewise, the suggested location of each proposed building or other improvement should be shown. Indicate existing improvements by solid lines; proposed ones by broken lines. Contours may be used where the topography warrants, or where specific problems exist in establishing grade. Show existing planting, such as trees, shrubs, etc. As proposed buildings are erected, the broken lines representing them on the prints may be changed to solid ones. If buildings are removed, corresponding erasures may be made to keep the map up to date. Sample Improvement Plan, Page 3 , shows the legend and general form suggested.

(2) Accompany each Improvement Plan Map with a description or record sheet typed on Atlas size paper.

It may contain data according to the following outline:

(a) Site:

(1) Brief description and location.
(2) The history of withdrawal or date and from whom purchased, cost, etc.
(3) Data concerning the improvements at time of purchase, the make-up of the yard, lawn, trees and other vegetation.

(b) Existing Improvements:

(1) Buildings, plan name, number or description, erection date. List buildings in order of importance or date of erection.

Show under each building:

1-a. Purpose
1-b. Overall dimensions of each
1-c. Number of rooms
1-d. Facilities provided
1-e. Description of materials used in construction
1-f. Statement regarding condition at time record sheets are prepared
1-g. Costs - original cost; improvement costs
1-h. Maintenance program

(2) Other structures.

Miscellaneous Improvements: -

2-a. Description of water, sewage disposal, electric and telephone systems and any other improvements.

(c) Proposed Improvements:

(1) Buildings, plan name, number or description, erection date. List buildings in order of importance or date of erection.

Show under each building: -

1-a. Purpose.
1-b. Overall dimensions of each.
1-c. Number of rooms.
1-d. Facilities provided.
1-e. Description of materials used in construction.
1-f. Statement regarding condition at time record sheets are prepared.
1-g. Costs - original cost; improvement costs.
1-h. Maintenance program.

(2) Other structures.

Miscellaneous Improvements: -

2-a. Description of water, sewage disposal, electric and telephone systems and other improvements.

(d) Landscaping:

(1) Give a description of landscaping.

1-a. Provide a landscape plan where required.
1-b. Where landscaping has been carried out according to plan, state when and by whom made, whether the proposed planting is completed or not.

(2) Describe any additional improvements, such as roads, drives, walks, lawn, flowers, shrubbery, or trees.

Photographs of a site and its improvements may be advantageously incorporated in this descriptive record. Place the photographs of the respective buildings, etc., as close to the description as possible.

2. Location and Grouping of Buildings or Structures on a Site.

A. General Considerations.

The principal building or buildings should be favored as to location in any group, and other buildings located according to their

relation to the principal buildings and to each other. Purpose, ease of approach, utility, and general convenience are most important in determining the location of each building in the group, as well as in deciding on the location and layout of the driveways and walks. The entire layout should fit the topography and utilize advantages offered by topographic features. Interesting tree growth and ground forms should be preserved. Any building can be made to "fit" the topography, but only after considerable remodeling of the existing surface. By following these principles of preservation and planning it will often be possible to secure desirable results without greatly changing the existing natural conditions. Architects and Engineers should secure advice and cooperation of Forest Service Landscape Architects on these important problems.

B. Utility

(a) Importance and Arrangement within the Group

Avoid a strung-out appearance in the grouping of buildings. Other things being equal, centralize the grouping of the buildings which have the greater amount of use and subordinate those which have only occasional use. The most important building should be located in the area with the most attractive setting, usually in the highest elevation and with good views. Quarters for temporary men should be so located as to obviate interference with the privacy of the ranger's family. For sanitary reasons, the barn should not be near the house.

Fuel storage may be provided in the basement or some part of the building. Where a wood shed is to be used, it should be located convenient to the back door of the dwelling, preferably not more than 25 to 50 feet away. It should be so located that it is screened as much as possible from the view of the visitor approaching the house, and at the same time be convenient for filling from trucks or wagons.

Where the dwelling has no basement, a cellar should be built near the kitchen or a frost-proof cold storage room provided above ground.

The garage for the Forest Officer's car should be reasonably near the dwelling, or a part of the dwelling itself.

Next in importance to the dwelling is the ranger's office building. Its location should be convenient for both the Forest Officer and the public. Usually the office should be located near the entrance to the administrative area.

Driveway, flagpole, hitching rack, and parking space for cars should be so arranged that visitors having business to transact will naturally go to the office rather than the dwelling.

Other buildings should be located secondary to the dwelling and office and be grouped from a standpoint of appearance, natural

setting, drainage, and accessibility for use. Page 3 is a sample Improvement Plan Map which indicates desirable grouping for certain assumed conditions.

Where space permits, buildings should be offset instead of being placed in line. This will afford balanced groupings for light, air and improved appearance and outlook.

(b) Parking Space

In any Improvement Plan ample provision for safe parking should be made. Parking areas for headquarters should be located to one side of the office or dwelling, preferably not in the view obtained while approaching.

(c) Driveways and Walks

For efficiency, the buildings must be so grouped that the "travel time" doing chores around the station is not excessive. The area of the station driveway and walks to be maintained must also be kept within practical limits.

C. Orientation of Buildings

(a) Geographic and Physical Conditions

Buildings should be made to "square" either with the topography or the line of a nearby highway, rather than with the cardinal directions of the compass. On sites where the adjacent topography has a well-defined direction, such as the precipitous face of a nearby mountain, buildings should square with the topography trends. Buildings should square with the highway where the site faces a highway. If a directional trend of topography is not evident, and there is no nearby highway, street or important road, then the buildings may square with the cardinal points of the compass.

Frequently, where adjacent towns are laid out in cardinal directions, or where other future development in the vicinity may be placed in accordance with the cardinal directions, then it is found desirable to conform to these established local conditions. Buildings surrounded by other buildings of private ownership should be oriented and placed so as to be properly related to these conditions. Local town and city ordinances should be consulted before the building is staked out.

Due to the natural possibilities of some topography, it may be desirable to place the principal buildings in the foreground position in some form of a circle, half circle, or some other geometric form. If the arrangement is not complicated or injurious to the approach or the utility of use of the principal or secondary buildings, such a plan should be considered.

(b) Alternation of Roof Lines

Roof lines of different buildings should not all run in the same direction, but the buildings should present an alternation of roof lines and gables. There is a chance that this instruction may cause conflict with utility of use in some cases. If this happens, let utility be the guiding factor in the determination.

3. Structures and Building Plans

A. Use of Approved Plans

Approved Plans and specifications must be followed. Changes in floor plan, design, finish, etc., shall not be made in the field except upon approval by the Regional Forester or his authorized representative.

B. Building Codes

Where buildings are constructed in towns or cities, work should conform to local building codes regarding plumbing, utilities connections, electric wiring, building materials, etc.

C. Errors in Plans to be called to the Attention of the Regional Office

If errors in plans or lists of materials are found in the course of construction, they should be reported promptly to the Regional Office so that corrections may be made.

4. Material Specifications and Lists of Materials

Where possible the Regional Offices should prepare, supplementary to all building plans, lists of materials to be attached to the invitation to bid, or as a part of the plan itself. The list should show key numbers, quantities, descriptions, and specifications of the grade and size or make-up of the material that is proposed for use.

Wherever specifications are used, it will be necessary to refer to or key to some definite known standard. Federal Specifications should be used wherever they apply. Where Federal Specifications do not apply and other standard specifications are prevailing for the type of material supplied, these specifications should be supplied to show the grade, size, and make-up. They should show whether or not they are standards acceptable to the American Society for Testing Materials, the National Lumber Manufacturers Association, or other recognized association, or whether they are equal or similar to some standard article of approved manufacture.

All material purchased should be inspected and must be of the quantity, grade and quality specified.

5. Existing Buildings or Structures

Where there are existing buildings which, because of their condition or standard of construction, justify further expenditure, they should be brought to such standard as will match the newer buildings and afford proper and approved utility.

Many old buildings are not worthy of further expenditure for maintenance, and their removal should be planned.

On those sites where a mistake has been made in the placement of a structure, consideration should be given to the possibility of moving the structure to the proper location, so that the group may be properly developed. There may be cases where it will be desirable to abandon present sites for Rangers' or other headquarters, and scrap or move present buildings onto new sites.

6. Maintenance

Necessary maintenance should be done annually on all existing buildings and structures. Emergency repairs should be made as needed, provided funds are available. Repairs should be made so that existing or adjacent work of the same kind is properly matched both in materials and workmanship. Programs for recurrent jobs such as painting should be worked out so that buildings are kept in proper condition and appearance.

CHAPTER II - CONSTRUCTION SCHEDULE AND WORK PLAN

7. Organizing the Job

When a man has been assigned to the management of a construction job, he should consider the entire project and decide upon the best method of doing the work.

He should first acquire a thorough knowledge of the plans and specifications governing the job. This knowledge should be so complete that he can not only visualize the completed structure as it will appear when erected, but also the various individual operations as they go forward in their proper order. This intimate knowledge is necessary in order that possible difficulties and conflicts of operations may be foreseen and costly errors thus averted.

In most instances, the man in charge will be furnished with detailed schedules of the work to be done, the materials required, and the records to be kept. When such schedules are not furnished to him, he should prepare the work schedules and material lists for his own information and guidance.

In making a schedule, work should be planned in proper sequence and should be organized accordingly. Available labor, technical and skilled, should be studied and so organized as to handle efficiently the work to be done.

8. Equipping the Job.

After the builder has thoroughly familiarized himself with the work to be done and the conditions under which it must be executed, and has planned the methods that he will employ, he is ready to plan on the machinery that will be necessary to carry out the work. The following may be considered as a general guide in determining procedure:

A. No piece of machinery or mechanical equipment should be taken to a job unless it will save enough labor to repay the cost of transporting to the job, setting up, taking down, and returning, plus a reasonable rental or share of its cost.

The greatest advantage from mechanical methods is obtained when the amount of work is large.

Work done on a Forest Service construction job other than on truck trails is inherently costly because of the impracticability of attaining a great degree of standardization of methods and conditions. Many jobs, therefore, require the minimum of machinery and the maximum of intelligent planning and execution.

No construction job is completely equipped without having on hand a full complement of wheelbarrows, jacks, sand and gravel screens, sledge hammers, mortar hoes, picks, shovels, axes, ropes, lanterns, wrenches, hacksaws, and numerous other small tools.

The jobs should be equipped with a chest containing all of the hand tools that are likely to be needed on the work. Provision must be made to quarter the tools in some handy adjacent structure, a large locked tool box or a temporary structure built for the purpose.

B. Sanitary facilities are to be provided on all jobs. Toilets, meeting the requirements of State and local sanitary regulations, must be provided and their use by construction crews enforced.

C. Arrangements must be made for a satisfactory supply of water, and it must be one that can be depended upon to furnish the required amounts needed at all times. In cities or towns, all that will ordinarily be required is a connection to existing pipe systems in accordance with whatever regulations or rules may be in force.

In the field, where a stream is available and analysis of the water shows it to be satisfactory for use, pumps or pipe lines to storage tanks will probably be the best arrangement. Gravity systems are preferred. Where no stream is available, it may be necessary to dig or drill a well. See Small Water Developments Handbook.

D. No trees except those within the building lines should be cut until detailed Improvement plans covering Landscaping have been prepared and approved. Trees selected to be retained in the final composition must be protected from damage during building or construction operations.

9. Care of Materials and Tools on the Job

All materials shall be thoroughly checked when delivered to the site, as to quantity, size, and grades specified.

After the materials have been delivered to the site, they must be properly stacked or housed to protect them from the weather or other abuse during construction. Conditions allowing abuse before use lowers quality and often causes expensive replacements or a resulting inferior standard of construction. Lumber or cement must not be placed on the ground, but should be carefully stacked or piled on platforms or cross sills. Finish and millwork, as frames, sash, wood and other trim, doors, fixtures, cabinets, etc., should be stored only in buildings where they will be dry and are protected from abuse. They should be arranged or stored so that they can be easily reached without undue handling when needed. Make sure that waste and loss are avoided.

Those responsible should not allow tools, nails, etc., to be widely scattered over the premises during the construction period. Tools should be gathered, checked, and locked up at the close of each day's work. The man in charge of a building job should be responsible

for any loss of tools.

The proper care and maintenance of construction equipment is highly important. Modern equipment and tools generally represent an investment of considerable money, and the life of the investment, as well as the rate of return earned upon it, will depend very largely upon the care given to maintenance.

Thorough cleaning-out of concrete mixers daily, for instance, is absolutely essential to the proper performance of their function of mixing concrete. Proper greasing and/or oiling of all moving parts will assure their continued operation at a lower cost and for a longer period than when such care is not provided. Tools, such as saws, planes, chisels, shovels, picks, must be kept sharpened and in proper condition for use.

Whenever the length or size of the job warrants, it is desirable to house as much of the equipment as possible.

10. Protection and Completion of Work

As work is completed, care must be taken to protect it until the job itself is complete. Much can be said about this subject, for it frequently happens that fine work in place is damaged by carelessness or because no effort is made to give it protection. In buildings, door frames, casings, jambs and sills, window sills and casings, stairs and floors generally, should be protected after being placed. They should be oiled before being exposed to the weather unless this interferes with the final finish.

All trees, shrubbery and natural landscaping around the building must be protected during construction in accordance with the proposed landscaping plan.

Proper sequence of work also helps to secure a first-class job. Keep the job in order. Remove waste materials and debris promptly. All unused materials should be kept in order and well protected.

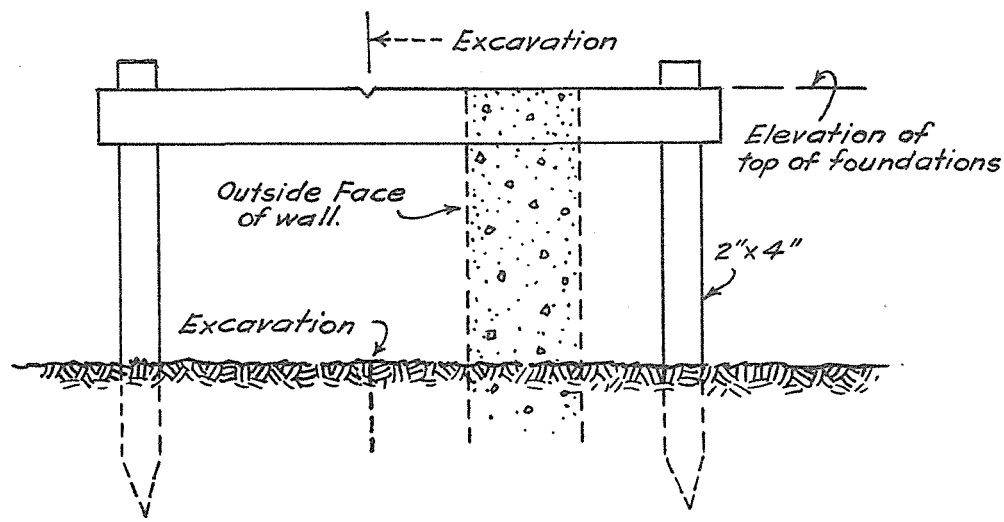
CHAPTER III - EXCAVATION

11. Lines and Grades for Buildings

The finished grade line should be established and a grade stake should be set and referenced. It should be located at some remote point, fully protected from building operations, so that it can be referred to from time to time as required. Axial or reference lines should be permanently referenced at points well beyond the limits of operations in order that they may be easily and surely re-established at any time during the progress of the work.

A. Batter Boards

Batter boards are defined as boards fastened horizontally to guide posts set so as to abut on the corners of an excavation for the foundation of a building to help the builders to establish lines and levels. The horizontal board is usually of 1 inch material and the posts are of 2" x 4" material. An illustration of a batter boards is shown below:

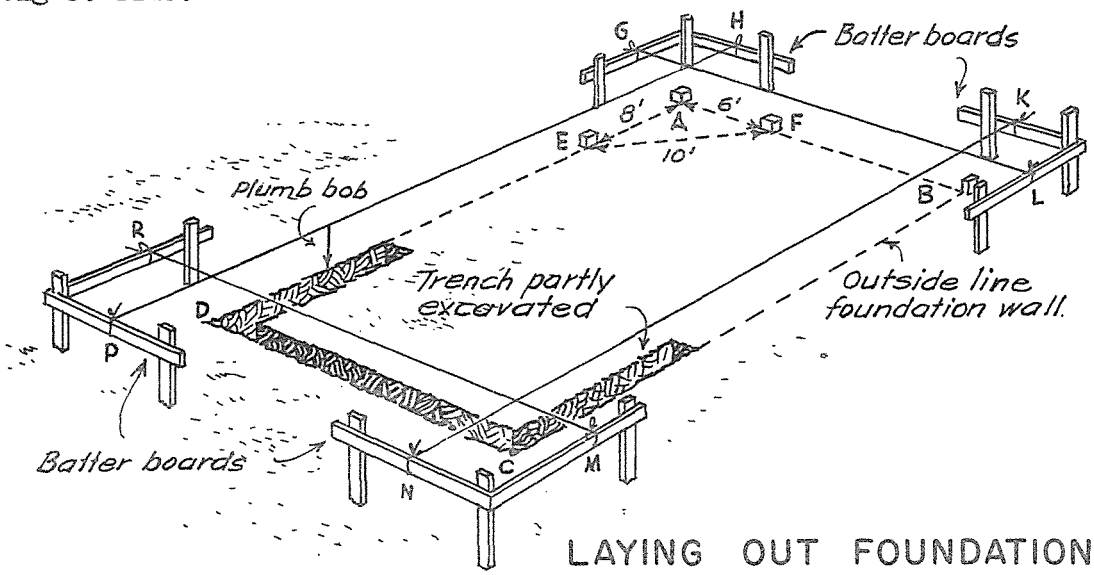


BATTER BOARD

The horizontal boards are nailed to the upright posts on an exact level and at a known elevation which has previously been determined by the surveyor. The corners of the buildings must be accurately located and stakes set before the batter boards are constructed. The building lines are then transferred to the batter board by stretching a chalk line from board to board with a plumb bob suspended from the line over the tacks in the corner stakes. Building lines are usually assumed to be the outside surfaces of siding or wall covering for frame buildings and the outside surfaces of masonry for brick buildings.

B. Laying Out Foundations

A typical arrangement of batter boards showing a practical method of laying out a foundation without a transit is given in the accompanying drawing. The easiest, quickest and most accurate way to determine the boundary line of a new building is by means of surveying instruments. When such instruments are not available, one of the simplest methods for laying out corners is known as the right triangle method. A triangle with sides six, eight and ten feet long is a right triangle, and the 90° angle or right angle is opposite the longest side.



LAYING OUT FOUNDATION

First, a base line AB is established, marking out one end or side of the new building. Stakes are set at A and B on this line, locating two corners. In the top of Stake A, a nail is partly driven to accurately locate the corner. On the line AB another stake is driven at F, 6 feet from Stake A. A nail is driven in the top of this stake exactly 6 feet from the nail in Stake A. Stake E should be driven so that its center will be exactly 8 feet from Stake A and exactly 10 feet from Stake F.

The corner represented by the angle EAF is a right angle; the line AE extended to D will form the second boundary line of the building, and D will represent the third corner. Other corners are located in the same manner. After this has been done, strings are stretched over the corner stakes, A, B, C, D, and carried to the outside supports called "batter boards" as indicated by G, H, K, L, M, N, P and R. The tops of the horizontal batters should be set at foundation level or at some other convenient "datum." The building lines may be projected from the strings to the ground by means of

a plumb bob suspended as shown in the drawing. When the batter boards have been set and the strings indicating the layout of the building have been transferred to them, the corner stakes A, B, C, D and the stakes E and F are removed so that the trench may be excavated. Nails should be driven into the cross pieces between the standards where the strings are fastened so that in case the strings are broken or removed, they can be accurately replaced. Having found the building line, it is easy to locate piers, posts, columns, or other intermediate supports.

After the points have been marked on the batter boards, lines should be stretched between batter boards along the building lines and all dimensions checked to see if they are correct. If the structure is rectangular and not too large, the diagonal distances between the intersections of the lines should be measured. If the lines are truly at right angles, these distances will be equal. When it is impossible tomeasure diagonals in this way, the system of employing the ratio of three sides of a right-angled triangle will serve as a check. When the lines have been established and proven true and square, the grades on all batter boards should be checked. When this has been done, the excavation may be started.

12. Lines and Grades for Trenches

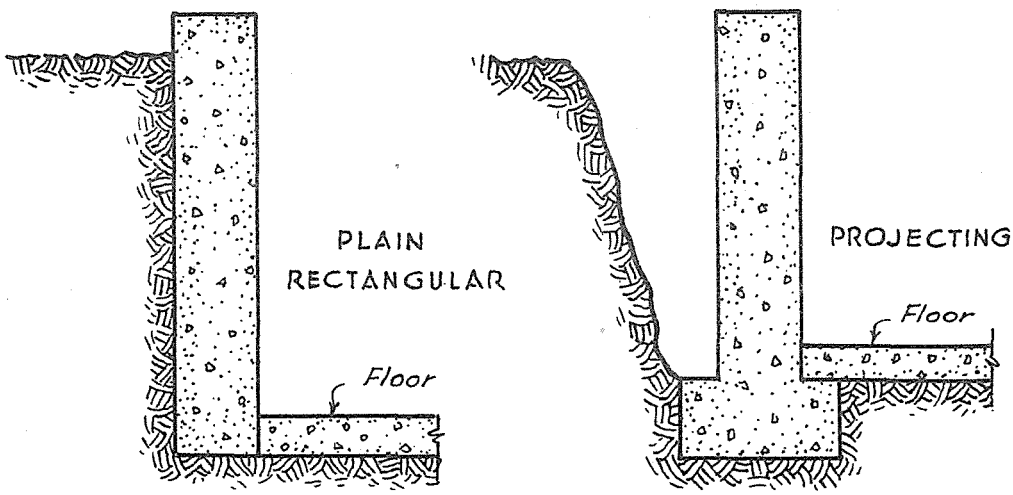
The location of a trench should be marked upon the ground by stakes driven at intervals along the center line. For careful work the depth of cut should be marked on each stake.

Before excavation has progressed to the point of disturbing the center line grade stakes, batter boards or reference boards should be erected across the trench at each stake. These are similar to batter boards for building excavations, and are nailed to stakes driven firmly into the ground on each side of the excavation. For wide trenches it may be preferable to lay a heavy timber or plank across the trench on the ground and fasten it in place. The center line and the elevation of the top of the board should then be marked on every reference board.

The correct depth of the trench can then be determined by measuring down from the top of the reference board. If the trench is to be quite deep, it may be desirable to nail a vertical piece, such as a 2 by 4 or a 1 by 6, to the reference board. One edge of this vertical piece should be on the center line, and a nail should be driven into that edge at a convenient, fixed distance above the grade of the bottom of the trench. The correct location for the nail is determined by measuring down from the top of the reference board. A line stretched from nail to nail will give the correct grade at any point between reference boards. After the nails are in place, their alignment should be checked by sighting along them.

13. Excavation Limits

Concrete walls are usually either of plain, rectangular cross section or with a projecting footing. Both types are shown below:



FOUNDATION FOOTINGS

Before an excavation is started, it is necessary to decide upon the lines of excavation. Where the walls are to be of plain cross section in firm soils, it is possible to save concrete form work by using the outside bank as a form and pouring the concrete against it. In this event the bank should be trimmed to the line of the outside surface of the wall. This should not be attempted unless the soil is of such make-up that it will not slough in any way. Considerable extra work may result from trying to maintain the bank on a carefully trimmed line. Where a failure or a crumble occurs, a greater amount of concrete will be required to fill the voids in the bank. There is also the disadvantage that injury to the concrete is possible because of sloughing material. A still further disadvantage is that the pressure of the wet concrete against the line of forms must be resisted by braces for there is no second line of forms to which the first can be wired.

As a general rule it will be found desirable to use forms for both sides of the wall. When double forms are used, the banks should be trimmed to a neat line at least 4 inches beyond the outside of the forms so that they may be removed after the concrete has set.

Where the excavation is done by a power shovel or other machine methods, it will not be possible to work close to the excavation line, and the earth bank should be sloped back to prevent sliding and sloughing while the excavation is being dug.

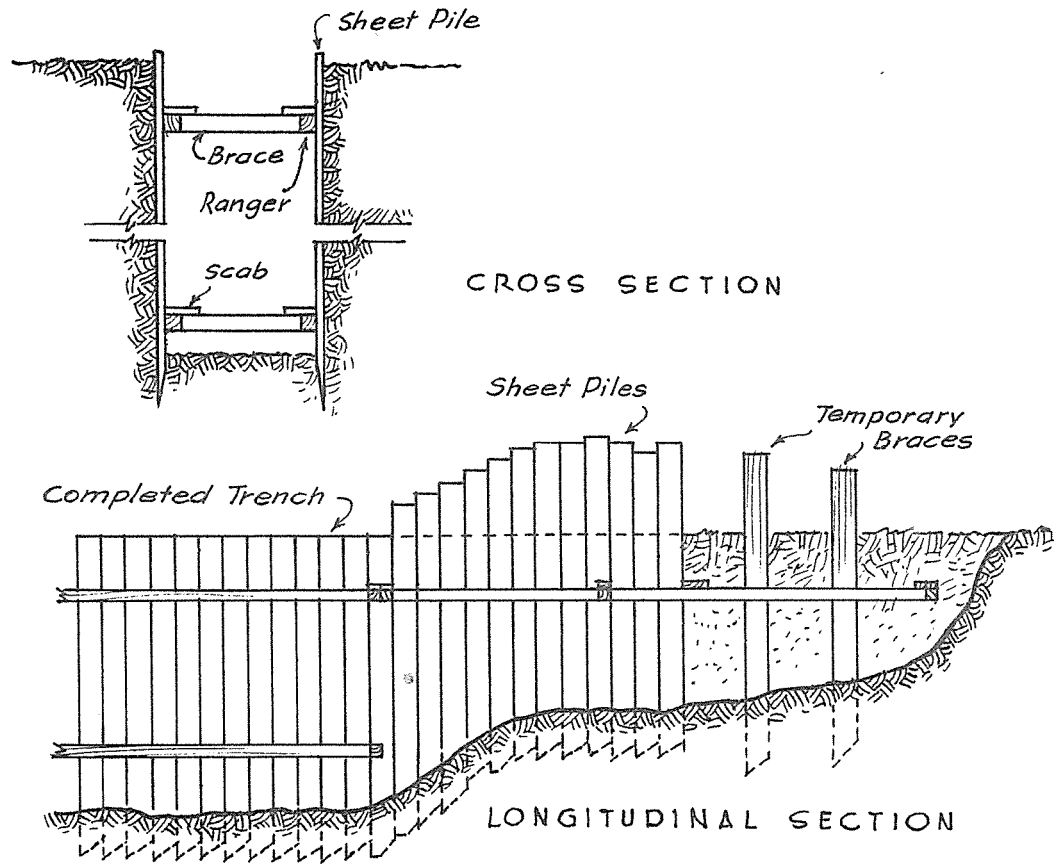
14. Sheet Piling and Bracing

A. Timber Sheeting

A detailed description of the procedure to be followed in constructing sheet piling is given in this article. Where building codes or State laws require other methods, they must be followed.

Where the earth has a tendency to slip or cave, or where movement may be accomplished or caused by other influences, sheet piling should be used for bracing. The most common method is the use of vertical sheet piling driven behind continuous lines of horizontal timbers called rangers. The rangers are braced at more or less equal intervals by timbers extending across the excavation from ranger to ranger.

A method of sheet piling a trench is shown below:



SHEET PILING METHOD

Sheet piling should never be less than 2 inches in thickness. The usual widths of sheeting are 6 inches and 8 inches. Although the 8 inch material costs more, the idfference in price between that and the 6 inch material can usually be balanced by the saving in labor and time. Sheet piling which is driven in wet earth should be made comparatively watertight by the use of tongue and groove or splined joints.

The required thickness of sheeting planks is governed by the load brought upon them. Forest Service Safety Requirements state that "size should be such that the allowable working unit stress should conform to recognized engineering practices." Sheet piling should usually be driven by a pile driver, but is sometimes dug in if the soil is extremely dry. Surface material is usually used to facilitate driving.

Rangers or longitudinal beams must never be less than 4" x 4". If the vertical spacing between them exceeds 4 feet and less than 6 feet, the size should be 4" x 6". When the vertical spacing exceeds 6 feet, the size must be in accordance with recognized engineering practices as regards the size and working stresses of the materials used.

Braces or struts are used to support the rangers. The size of the material used is governed by the size of the rangers they support. Braces are held in place by the use of scabs or short pieces of plank nailed as shown in the illustration on Page . Braces are usually spaced 8 feet apart to provide working space between them. Suitable sizes of bracing for different widths of excavation, and for depths not exceeding 8 feet, are shown below:

Size of Braces

Width of Excavation Feet	Size of Brace Inches
4	4 x 6
8	6 x 6
12	8 x 8

B. Steel Sheeting

Steel sheet piling is used extensively for carrying excavations through extremely wet soil. All steel sheeting offers more resistance to bending from lateral earth pressure than wood sheeting. Rangers may be spaced farther apart, but their strength must be increased to take up the additional load coming on them.

The character of the soil through which the sheeting is to be driven must be considered in deciding upon the form of sheeting to be used. The more simple, straight, heavy webbed sheeting will penetrate hard, gravelly soils with less danger of deformation than arched-web sheeting.

Complete data as to weights and dimensions of certain sections may be obtained from the manufacturers.

15. Cofferdams

Suitable and practically water-tight cofferdams should be used wherever water-bearing strata are encountered above the bottom of the excavation. Cofferdams or cribs for foundation construction should be carried well below the bottom of the footings, and should be well braced and as water-tight as practicable. The interior dimensions of cofferdams should be such as to give sufficient clearance for construction of forms, for the inspection of their exteriors, and to permit pumping outside of the forms.

Cofferdams should be constructed so as to protect green concrete against damage from the sudden rising of a stream and to prevent damage to the foundation by erosion.

No timber or bracing should be left in cofferdams or cribs in such a way as to extend into the substructure masonry.

16. Controlling Water

In many excavations water is encountered, and, unless controlled, will seep into the excavation and interfere with the work. The inflow of water from the sides may be greatly decreased by the use of either tongue-and-groove or splined sheeting or steel sheet piling.

If water has found its way into the excavation, adequate measures should be adopted for handling it. In some work a subdrain may be built in the bottom of a trench to carry off the water. These drains may be formed by the use of clay tile pipe, the upper joints of which are covered with burlap, or may be boxes made of wood, brick or steel. They may also be subgrade channels, which are filled with loose stones. Where the wooden box drain is used, holes should be bored into the sides to allow the water to enter and pass to the sump. Drains may connect the sump to a low point beyond the building or structure, or the sump may serve as a collecting basin and a suction pump may be used.

Movement of particles of earth or sand by water can usually be stopped by placing crushed stone on the subgrade close to the sheet piling. The crushed stone is usually too heavy to be moved by water flowing up from the bottom of the excavation. Sand bags may also be used for the same purpose.

A pump must be used when gravity methods fail to remove water from an excavation. Tye type, style and kind of a pump will depend not only on the quantity of water, but upon the height to which it must be lifted. Care must be taken to prevent the water emitted by the pump from causing erosion of the soil. See the Small Water Developments Handbook.

The practical suction limit for a pump is about 15 or 20 feet. When excavations exceed this depth, it will be necessary to use a pump capable of forcing the water through a discharge pipe to the desired height. A centrifugal pump is well adapted to this work because it was designed to work against a pressure in the discharge line equal to the weight of water in the line.

A floor slab should be heavy enough to resist the lifting pressure of the water from beneath. Floors in basements and reservoirs must be of sufficient thickness to counter-balance the water pressure by their own weight, or they must be reinforced with steel to prevent cracking. Where the reinforced floor is used, the required weight to keep the structure from floating must be derived from the load on the walls.

17. Rock Drilling and Blasting

This subject is covered thoroughly in the Truck Trail Handbook. The instructions in the Handbook should be carefully followed when work of this type is to be handled.

18. Removal of Blasted Rock

The kind of rock, the spacing and layout of drill holes, and the size of the explosive charges used will all have a direct effect on the size of the fragments which result from a blast, and on the methods of their removal. Where blasting is done, mats should be placed over holes as a precaution against injury or damage to nearby objects or buildings.

Usually heavy charges of explosives and close spacing of holes will result in the rock being broken into small pieces which can be readily handled. If it is necessary to be particularly careful because of the proximity of buildings, the rocks should be broken into large pieces. These will have to be pried loose with bars and loaded on stone boats of steel plate or plank construction to be hauled by teams or tractors.

The kind of transportation will have to be adapted to the particular type of work, the length of haul and other conditions peculiar to the job. See the Forest Service Truck Trail Handbook.

Wheelbarrows used for hauling excavated rock should be of all-steel construction so that they may be able to withstand rough usage. Round-pointed shovels are best for shoveling broken rock. Picks used for handling broken rock should have short points. Specially manufactured rock picks or old picks which have been resharpened with short points, may be used.

Sledges weighing from 16 to 20 pounds should be used for breaking large pieces of rock. The striking edge should not be circular, but should be elongated in the direction of the handle.

Blows from the elongated edge of the sledge will have a tendency to split the stone. The handles for such sledges should be slender and springy so that they will absorb the shock from the blow.

Where it is impossible to use explosives in excavating rock or removing old concrete, wedging may be used. Wedging is usually accomplished by the use of two wedges, one on each side of a drilled hole, into which a round plug is driven. As the plug is driven, it acts on the beveled surfaces of the two wedges and causes the rock to break. It will often take many holes and many wedging operations to split a rock. Air hammers may be necessary to break up rocks so that the required surface or finish may be secured.

19. Finish of Excavation

Where it is necessary to remove large boulders, rock ledges, logs or other obstacles below the excavation grade line, the resulting holes must be carefully refilled. The weight of the working equipment, such as tractors, scrapers, etc., is not sufficient to pack the loose material to the same compactness as the undisturbed ground foundation. All fills which are to support foundations must be compacted to a consistency equal to the undisturbed foundation material before buildings are erected. This is particularly essential where such fills occur beneath heavy construction such as abutments, brick or rock fireplaces, etc. To obtain the maximum compaction it is necessary for the fill material to have the proper moisture content. For most soils this is approximately the maximum amount of moisture at which equipment can be operated over the fill without bogging down. The fill should be built in layers from 3 to 8 inches thick and compacted by hand tampers or tamping rollers, depending upon the size of the fill. For proper methods of compacting fills, see the Handbook on Design and Construction of Forest Service Dams.

All rock or other hard foundation material should be cleaned and cut to a firm surface, either level, stepped or serrated. All seams should be cleaned out and grouted. All loose rock and disintegrated rock and thin strata should be removed. When masonry is to rest on an excavated surface other than rock, special care should be taken not to disturb the bottom of the excavation. The final removal of the foundation material to grade should not be made until just before the masonry or concrete is to be placed.

20. Disposal of Waste Earth and Materials

One of the important parts of excavation work is the disposal of waste materials involved. Quite frequently these materials are handled more often than necessary. The most economical means of handling shouldnbe employed and the materials should be moved with dispatch to the point of waste. The economical haul or handling will depend to a great extent upon local conditions. Any movement of earth or rock in excess of 150 feet should be handled by teams and

scrapers, or by mechanical equipment. See the Forest Service Truck Trail Handbook. Mechanical equipment can often be used to advantage even on smaller work. The excess material should be wasted at such a point that it will not interfere with the work. Waste dumps should be located in accordance with good landscaping principles, and should not become a blemish on the site itself or in some other location.

It is often desirable to remove the top soil and store it so that it may be used later in landscape planting and development work at the building site or at some other nearby site.

Where material from an excavation is used to raise the grade of a site, it should be laid in layers and carefully rolled or tamped. In no case should the newly deposited layers be greater than 12 inches in depth before being tamped in place and new layers added.

21. Backfilling

After the building or structure has been completed, the areas around the foundation should be filled to the level of the original surrounding surfaces or the new grade. The fill should be made in layers not over 12 inches thick, and should be well compacted. Materials which will not compact readily should not be used in this work. When sufficient suitable material is not available from the excavation, additional material should be obtained from borrow pits.

Wet foundations should be drained by placing agricultural drain tile around the footings. A minimum of 24 inches of well graded porous material should be placed directly over the til before random material is used for backfilling. If it is not desirable to use drain tile, a French drain of durable stone may be used instead.

Fills placed around piers should be deposited on both sides to approximately the same elevation at the same time. All filling adjacent to structures should be deposited in horizontal layers and well compacted. Special care should be taken to prevent any wedging action against the structure. The slopes bounding the excavation should be stepped or serrated to prevent such wedge action.

In filling over reinforced concrete culverts which are to be buried more than 3 or 4 feet, the backfilling should be carried to the elevation of the top of the culvert and thoroughly compacted by puddling or other suitable means before filling over the top.

CHAPTER IV - FOOTINGS AND FOUNDATIONS

22. General

The weight of any structure plus the load or loads it is to carry must be transferred to the earth on which the structure is to rest. The size and make-up of foundations and footings depends on many conditions, but in general it may be summed up that the stability of a structure is dependent upon the ability of the foundation and footings to properly transfer to the foundation bed the weight of the structure and the loads imposed upon it. Foundations will usually be of stone masonry, plain concrete and reinforced concrete, although they may be of brick masonry or structural steel.

Foundations may fail in three ways: (1) by crushing of the materials composing the foundation bed, (2) by unequal settlement, or (3) by failure of the materials in the foundation structure itself.

Crushing of the foundation bed will occur when the pressure of the footing and foundation on the foundation bed exceeds the strength of the material on which the footings rest. In order to design footings and foundations properly, the strength of the soil is sometimes determined experimentally. The foundation is then designed so as to bring on the soil only about 10% to 12% of the ultimate pressure the earth could support. By so designing, it is intended to keep the pressure on the foundation bed within safe limits. Where the design of a foundation and footing is not the direct result of soil bearing studies or experiments, it is usually based on known data concerning different kinds of soils. Even then, test pits, holes or drill cores are essential for the proper application of the data.

Foundations may fail if the pressure upon the foundation bed at one place is greater than at another, because all soil is compressible in proportion to pressure. Where the pressure is greatest, the soil is compressed the greatest, and unless the weight of the structure is uniformly distributed over the foundation bed, unequal settlement is likely to occur. Should the weight be unequally distributed, the structure will settle more at one point than at another, and cracks will result. The settlement may ultimately cause the structure to collapse.

Failure of the materials in the foundation itself may be caused by improper design or by the use of defective materials.

23. Foundation Soils

The foundation bed of a structure consists of the materials of the earth on which the building will rest. They may be solid rock, loose rock, earth or sand in whatever condition they may be found. In some cases they may all be met in the same foundation bed.

Rock, when in its undisturbed position, forms the best foundation and is always the preferred foundation bed material. It may be relied upon to support any ordinary structure. Other materials have lesser values as supporting materials. The table below gives the value of various materials in supporting structures:

Soil Bearing Capacities
(Tons per square ft.)
Use Local Building Code
where same exists.

Ordinary Soils, Dry	1
Ordinary Soils, Wet	1/2
Soft Clay	2
Wet Sand	2
Firm Clay	2
Sand & Clay, mixed or in layers	2
Fine and dry sand	3
Hard dry clay	4
Coarse sand	4
Gravel	6
Soft Rock	8
Hard Pan	10
Medium Rock	15
Hard Rock	40

Generally, it will not be safe to trust to surface appearances when judging the character, strength and soundness of foundation beds. Rock that appears to be solid may be only a thin stratum, or it may contain fissures or other defects, or it may be underlaid with a body of soft clay or other soft material. Likewise, an apparently satisfactory bed of clay may be only a thin layer underlaid with sand. Conditions might be such that water could reach and carry away the sand and undermine the clay, thus undermining the footings and foundations, and causing the structure on it to fail. It is, therefore, urgently necessary to carefully investigate the material on which a foundation is to rest and also all the conditions surrounding the site.

It is desirable to have a knowledge of the geology of the region concerning the extent, character and succession of the local formations, lay of the strata, character of the bearing afforded and prevalence of faults or other irregularities in the soil make-up.

Greater precautions should be given areas which have been disturbed by upheavals of the earth and on which the stratifications are inclined or broken up. Loading tests may be resorted to where doubt exists after all reasonable investigations have been made. A method should be selected and followed which will give the data desired.

Where the building to be erected is secondary in importance and the weight to be carried is small, or comparatively so, the character of the foundation may usually be determined accurately enough from the nature of nearby or neighboring strata and the outcrop in nearby streams, washes or ravines.

The extent to which soil tests should be made is determined by the character and size of the job. On important and large jobs test holes should be dug or drilled, particularly where there is some reason to expect defects or irregularities. In these cases, apparatus should be used which yield complete samples, or cores of the material passed through. After proper examination, the recovered cores may be preserved for future reference.

Numerous tests on the same site frequently disclose subterranean defects in the foundation bed and furnish valuable information for the design of the foundation. The tests may be of the open pit or well type or by borings similar to those used in rock drilling.

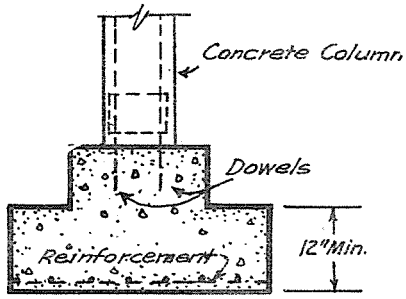
Where layers of sand or other soft materials are encountered, it may be necessary to drive a casing as the drilling progresses. This is especially necessary if the materials do not have enough stability to maintain the wall of the bore hole, but cave or slough into the hole and obstruct the operation of the drill.

Other test methods are used for larger holes. One method uses a suitable earth auger, which excavates and brings up the material in its natural condition.

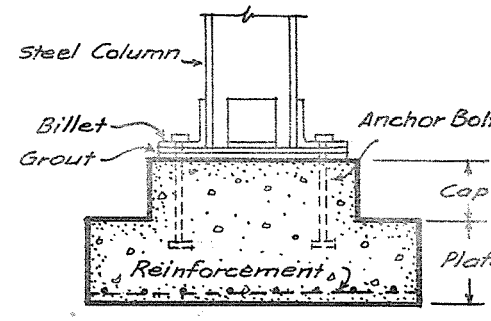
Another system uses water from a jet to partly loosen the material being raised by an auger or a drill. In this system the drill rod is hollow, the water escapes at the drill end, and rises between the drill and the casing and in this manner brings up the excavated materials. See Handbook on Design and Construction of Forest Service Dams.

24. Areas of Foundation Bed and Footings Required

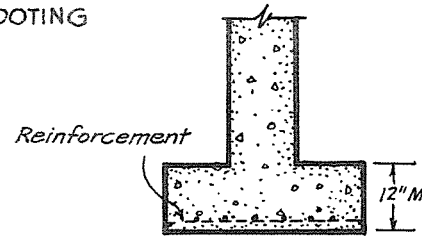
In the case of ordinary structures, where weight is the only force resisted and where the weight is uniformly distributed over the whole foundation, the area of the foundation bed or footing is of little concern where the formation is solid rock. Where earth or sand foundation beds must be utilized, care must be taken to distribute the weight to be carried over an area large enough so that the resistance of the foundation bed material will safely exceed the applied weight. Should the plan be irregular, or other forces occur so that it is difficult to secure a uniform pressure over the entire area covered by the foundation bed, extra precautions are necessary.



REINFORCED CONCRETE ON SPREAD FOOTING

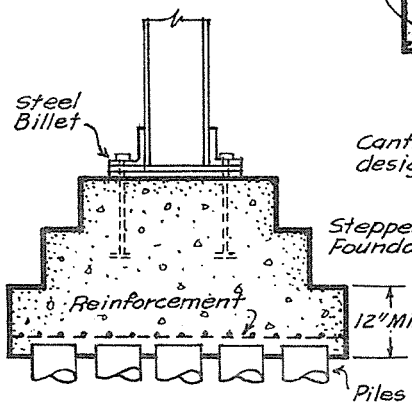


STEEL COLUMN ON SPREAD FOOTING

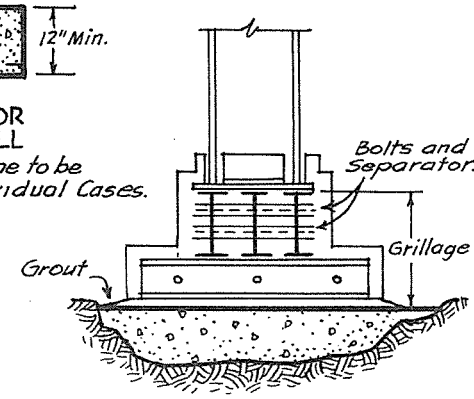


FOOTING FOR HEAVY WALL

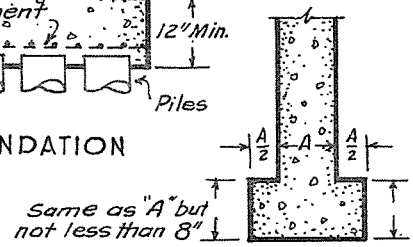
Cantilever span type to be designed for individual Cases.



PILE FOUNDATION

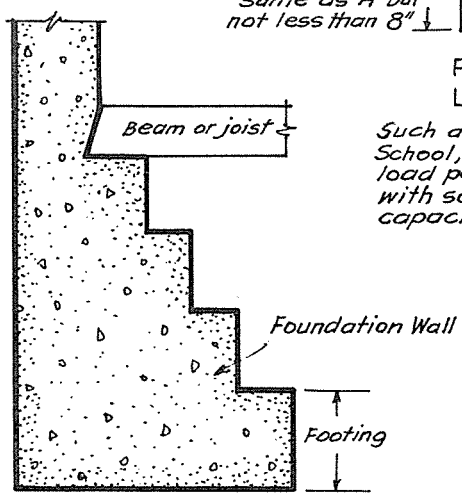


STEEL GRILLAGE FOUNDATION

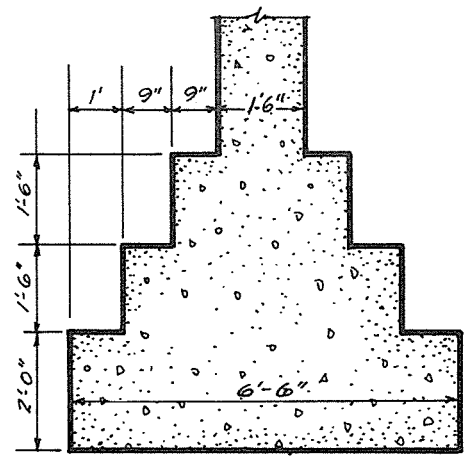


FOOTING FOR LIGHT WALL

Such as for house, School, etc. Check load per square ft. with soil bearing capacity.



ECCENTRIC LOADED FOOTING



Assume soil calls for 6'-6" wide footing, depth of steps to be twice their projection.

MASS CONCRETE FOOTING HEAVY WALL OR CHIMNEY

FOOTING DETAILS

Earth and clay foundation beds are more or less compressible, and the amount of compression is in direct proportion to the intensity of the applied pressure. Therefore, slight variation in settlement of different parts of the foundation bed may distort or disrupt the building erected upon it. It is always best to avoid compressible foundation beds when possible. Where this cannot be done, the width or bearing of the footings should be designed to equally distribute the load per unit of area.

Forest Service building plans generally have foundation and footing designs which, if followed, will provide satisfactorily for this distribution when used over firm clay or gravel foundation beds.

In buildings that have restricted sites where walls or columns are placed close to adjacent or adjoining property lines, it will be quite impossible to arrange for simple concentric loadings on the footings. In such a case it will be necessary to use offset footings, cantilevers or other devices to transfer the loads to supporting areas located on the property.

Eccentric loading due to offset footings involves possible failures unless the design and construction are carefully planned and worked out. These failures may be in shear or rotation of the footing or a failure in the foundation wall through horizontal cracking.

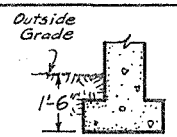
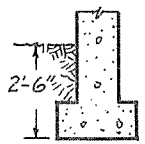
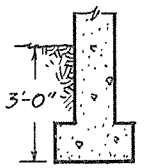
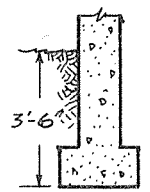
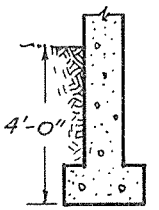
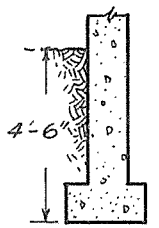
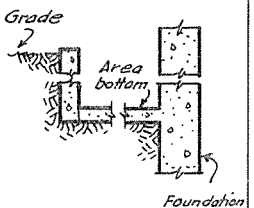
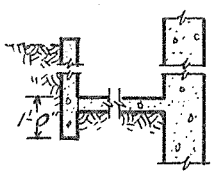
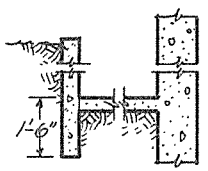
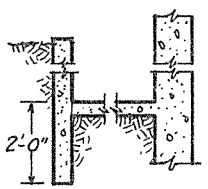
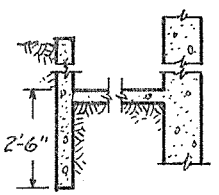
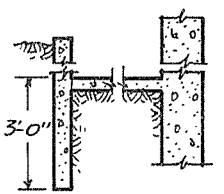
A good type of construction for eccentric loading is illustrated on Page 28. In this type of construction the floor beams are set into the wall, and the foundation wall has a continuous stepped appearance or batter from the footing level up to the level of the beams. This system should not be used for piers.

No part of a foundation structure should, under any combination of loadings, be stressed beyond safe limits. The possibility of future additions or changes in a superstructure or changes in the use of a building should be kept in mind.

25. Depth of Foundation for Forest Service Structures

The important point in constructing bridge abutments or piers from Forest Service plans is to make sure that the footing is deep enough so as not to be subject to scouring. If necessary, the foundation should be protected from erosion by riprap or sheet piling. In sandy or alluvial soils, timber bents or piles should be used, depending upon whether the stream is liable to erode the bed. Where piers are constructed in the main part of the stream, they should be set practically parallel with the direction of the flow in order to prevent obstructing or deflecting the flow and causing bank erosion.

For buildings, the depths of the foundations will be dependent on soil bearing qualities as mentioned heretofore and on the depths generally accepted as good practice in various sections of the country, on account of frost action.

TEMPERATURE	No Freezing weather. South Florida, So. Carolina, So. Texas	Where minimum temperature is +20°	Where minimum temperature is +10°	Where min. temperature is 0° New York - Cent. States	Where min. temperature is −10° Northern Atlantic States	Where temperature goes below −20° N. Dakota - Canada.
FOUNDATION WALLS						
AREA WALLS						

Same dimensions apply with Brick or Stone Walls.
Minimum Temperature (Fahrenheit) means that these temperatures are reached for periods of days and not just for a few hours. These minimum temperatures are 10° to 15° above lowest recorded and are the same used for calculating heating requirements. Consult Building Code for depth requirements where same exists.

DEPTHS REQUIRED BY BUILDING CODES

Albuquerque, N.M.	10" Below Gr.	Denver, Colo.	1'-6"	Louisville, Kentucky	2'-6"	Omaha, Neb.	3'-0"
Atlanta, Ga.	Below grade	Detroit, Mich.	3'-6"	Milwaukee, Wis.	5'-0"	Portland, Ore.	No mention
Baltimore, Md.	3'-0"	El Paso, Tex.	No Mention	Minneapolis, Minn.	No mention	Philadelphia, Pa.	3'-0"
Boston, Mass.	4'-0"	Halifax, Canada.	4'-0"	New Orleans, La.	No mention	St. Paul, Minn.	4'-0"
Butte, Mont.	3'-0"	Jacksonville, Fla.	1'-0"	New York, N.Y.	4'-0"	St. Louis, Mo.	2'-6"
Chicago, Ill.	4'-0"	Kansas City, Mo.	3'-0"	Winnipeg, Canada.	No Mention	Salt Lake City	No mention
		Seattle, Wash.	1'-6"	Washington, D.C.	No mention.		

FOUNDATION AND AREA WALLS

Illustrations and data showing proper depths of foundation walls on account of extreme temperatures are shown on Page 30 .

Deep foundations are necessary when the material at the level at which footings would ordinarily be constructed is not suitable, or when it is desirable to carry the foundations of the structure down to an underlying stratum of greater supporting power.

When it is necessary to build upon a compressible soil of considerable depth, the most practicable method of obtaining a solid and lasting foundation for structures is with piles. Where the foundation soil is constantly saturated with water, wood piling will last indefinitely if cut off below the low water level.

Where the foundation soil is alternately wet or dry, either treated wood or concrete piling should be used. Treated piling should last from 20 to 25 years. See Chapter on Wood Preservation for treated wood piles.

Piles should be capped, either with large stone blocks, concrete blocks or a timber or steel grillage.

For Forest Service work, rock or concrete should generally be used. Materials of construction should be proof against all deteriorating influences, and if the materials are subject to deterioration, they should be permanently protected. See Chapters on Piling, Concrete, Masonry and Brick Construction, and also Wood Preservation.

26. Placing of Footings and Choice of Materials

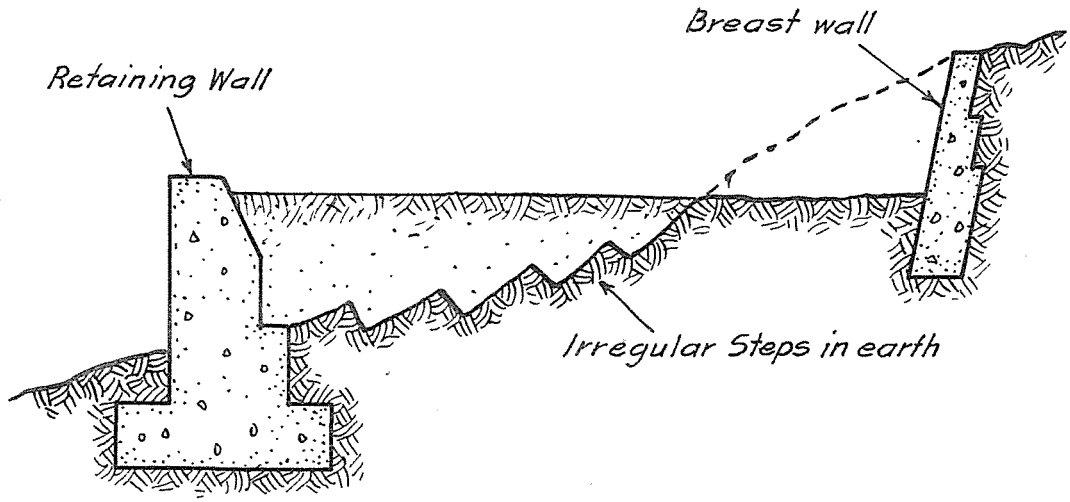
Where the material of a foundation bed is inferior in strength to the material of the structure it becomes necessary to accommodate one to the other in order to secure equal strength throughout. The problem is to distribute the load carried by the structure over such an area of the foundation bed that its safe unit load is not exceeded. This is accomplished by enlarging the base of the foundation so that it may cover an area of the foundation bed, the resistance of which will be at least equal to the weight of the structure. Page 28 shows "Typical Footings" and ways of handling spread footings for all ordinary cases.

Footings should be carried to such a depth that the slope from the bottom of the footing to any adjacent deeper excavation does not exceed $1\frac{1}{2}$:1.

27. Retaining Walls

A retaining wall is designed and built to resist the pressure of the earth or other material behind it. It differs from a breast or face wall in that breast walls are erected only to prevent weathering or disruption of earth or other material which is in its undisturbed natural position and which is sufficiently stable to support itself unless disturbed.

There are a number of reliable sources of data available for use in the design of retaining walls for various conditions. There are so many conditions, however, that in practice, it is impossible to determine the exact thrust which will be exerted against a wall of a given height. The thrust may be dependent upon the cohesion of the earth, the dryness of the material, the method of backing up the wall, etc. It is, therefore, necessary in designing a retaining wall to make certain assumptions regarding the behavior of the material back of the wall.



RETAINING WALL CONSTRUCTION

The tendency of the backing to slip is very much less when the material is in a dry state than when it is saturated with water, and every precaution should be taken to secure good and proper drainage. Besides surface drainage, there should be openings left in the wall for the escape of the water which may accumulate behind it. The manner in which the material is filled against the wall also affects the stability of the backing. If the original ground is made irregular with steps, and the earth well rammed in layers inclined down from the wall, the pressure will be less than where the earth is placed in layers sloping down toward the wall.

Cases may occur where only a limited amount of fill material is placed behind the wall on top of the original slope of the grade. This does not offer quite the opportunity for tamping and sloping as outlined above.

The angle of repose is the angle of the natural slope of the material. The Slopes of Repose, Angles of Repose and Weights of Loose Materials are given in the following table:

Kind of earth	Slope of repose*	Angle of repose	Weight in lb. per cu. ft.
Sand, clean, dry	1.5 to 1	33° 41'	90
Sand and clay	1.33 to 1	36 53	95
Clay, dry	1.33 to 1	36 53	100
Clay, plastic	2 to 1	26 34	100
Gravel, clean	1.33 to 1	36 53	100
Gravel & clay, dry	1.33 to 1	36 53	100
Gravel, sand & clay, dry	1.33 to 1	36 53	100
Soil	1.33 to 1	36 53	100
Soft rotten rock	1.33 to 1	36 53	110
Hard rotten rock	1 to 1	45 00	100
Bituminous cinders	1 to 1	45 00	45
Anthracite ashes	1 to 1	45 00	30

*The slope is that of horizontal to vertical projection.

As a guide to the erection of retaining walls see Page 32, which illustrates general methods intended to serve in ordinary cases that do not require special designs or studies. Where such cases exist, special designs should be used for the particular problem at hand. The studies should be made by a competent engineer.

Details of construction are such that retaining walls are built over a substantial footing and with a battered or sloping face, or they are so constructed that their footings will prevent rotation or overturning due to the pressure of the material behind the wall. Where the ground freezes to a great depth, the back of the wall should be sloped forward for 3 or 4 feet below its top surface, and this slope should be quite smooth, so as to lessen the hold of the frost and prevent displacement. Where the ground to be supported is firm and the strata are horizontal, breast walls are usually built more to protect than to sustain the earth. It should be borne in mind that a trifling force skillfully applied to unbroken ground will keep in place a mass of material which if once allowed to move would crush a heavy wall. Great care should, therefore, be taken not to expose the newly open ground to the influence of air and water longer than is necessary for good and sound work. Care should also be taken to avoid leaving the smallest space for motion between the back of the wall and the ground.

The strength of a breast wall must be proportionately increased when the strata to be supported incline down towards the wall. Where the strata incline down away from the wall, the latter may be little more than a thin facing to protect the ground from disintegration. The preservation of natural drainage is one of the most important points to be maintained in the erection of breast or retaining walls, as their stability depends upon this in a great measure.

No definite rules can be laid down which will fit every case. Therefore, careful consideration must be given to every particular problem.

28. Waterproofing and Protection against Action of Alkali Soil

Foundation walls below grade, in alkali soil, should be given one or two coats of standard waterproofing material. A layer of tarred felt should be embedded in the brick mortar just above the finished grade to prevent alkali from creeping up into the brick work.

Waterproofing of concrete foundation walls is described in the Chapter on Concrete.

CHAPTER V - PILING AND PILE DRIVING

29. Choice of Species for Piling

The desirable properties of piles include sufficient strength and straightness to withstand driving, ability to carry the weight of structures built on them, and in some instances, ability to resist bending stresses. Resistance to decay or ease of penetration by preservatives is also important. Piles for temporary use or piles that will be in fresh water entirely below the permanent water level do not have to be resistant to decay.

Douglas fir, larch, southern yellow pine, and oak are among the principal species used for piling of required high strength. Lighter weight species, such as western red cedar, are sometimes used where driving resistance is moderate. Numerous other species are also used when strength or durability requirements are not exacting.

Specifications for timber piles covering kinds of wood, general quality, resistance to decay, dimensions, tolerance, manufacture, inspection, delivery and shipment have been published in the American Railway Engineering Association Manual. Specifications for timber piles have also been prepared by the American Association of State Highway Officials, the American Society for Testing Materials and the American Standards Association.

30. Bearing Loads for Piles

Piles are classified into two groups, depending upon how the load is sustained:

(1) The pile tip rests on a solid stratum which carries the load. There is little or no friction along its sides.

(2) The pile receives practically all its support from earth friction along its sides.

Piles in group 1 are considered as columns and designed accordingly. The strength of those piles in group 2 where a large proportion of their length extends above the ground must also be considered on the basis of long columns. In such instances, bracing is usually possible to reduce the unsupported length.

The determination of the load-carrying capacity of piles classed in group 2 is a subject on which there is considerable diversity of opinion among engineers. Many experienced engineers have little faith in any formula for bearing capacity of piles, and advocate basing design in each instance on experience and observation of the behavior of pile foundations under similar conditions or on results of static loading tests. A general discussion of the various

formulae given in engineering handbooks and other literature is, therefore, beyond the scope of this handbook.

In determining the number of piles required in a bent, an allowable load of 600 lbs. per square inch of average cross-sectional area may be used. As an example, assume that it is desired to drive piling having an average diameter (d) of 10". Area = .785 d^2 = .785 x 100 = 78.5 square inches. Then the allowable load = 600 x 78.5 = 47,100 lbs. Allowance of such loads is contingent upon proper setting of the piling. In view of widely varying soil conditions, the usual way of arriving at the carrying capacity of a pile is by computation from data on the action of the piling while being driven. Formula (1) gives the supporting capacity of a pile for various rates of penetration, while formula (2) gives the average penetration that should be obtained for any required supporting capacity.

These formulae are based on: (a) firm head on piling; i.e., pile head is not broomed or crushed; (b) penetration is reasonably quick and uniform; (c) no appreciable bounce of the hammer or bending, kicking or staggering of the pile.

p = safe load per pile in tons
w = weight of hammer in tons
h = free fall of hammer in feet
s = average penetration in inches of pile during last 5 blows

For a drop hammer the formulae are as follows:

(1) $p = \frac{2\ w.h}{s + 1}$ (2) $s = \frac{2\ w.h}{p} - 1$

If a steam hammer is used, the formulae change to:

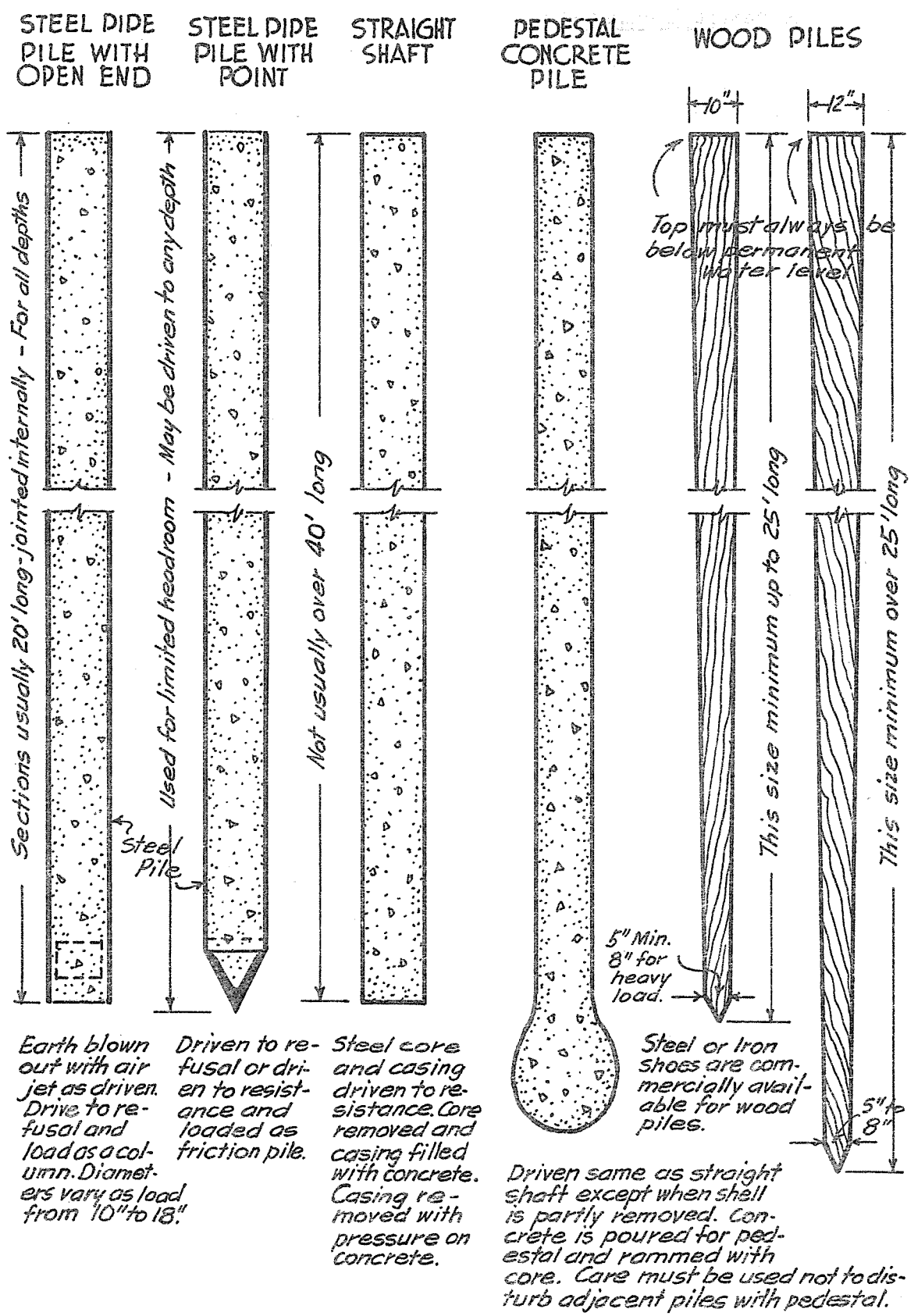
$p = \frac{2\ w.h}{s + 1/10}$ and $s = \frac{2\ w.h}{p} - 1/10$

Example "A": What is the supporting capacity of a pile driven with a hammer weight 2,000 lbs., having a free fall of 10 ft., giving an average penetration of 1/2 inch? Substituting in formula (1) we have:

$$p = \frac{2 \times 1 \times 10}{.5 + 1} = \frac{20}{1.5} = 13.3 \text{ tons.}$$

Example "B": With the same driving equipment as that used in Example "A", what penetration during last 5 blows, should be had to give 10 ton supporting capacity per pile?

Substitute in formula (2): $s = \frac{2 \times 1 \times 10}{10} - 1 = 2-1 = 1$ inch


STEEL PIPE PILE WITH OPEN END
STEEL PIPE PILE WITH POINT
STRAIGHT SHAFT
PEDESTAL CONCRETE PILE
WOOD PILES
10"
12"
Top must always be below permanent water level
Sections usually 20' long-jointed internally - For all depths
Used for limited headroom - May be driven to any depth
Not usually over 40' long
Steel Pile
This size minimum up to 25' long
This size minimum over 25' long
5" Min.
8" for heavy load.
5"
8"
Earth blown out with air jet as driven. Drive to refusal and load as a column. Diameters vary as load from 10" to 18".
Driven to refusal or driven to resistance and loaded as friction pile.
Steel core and casing driven to resistance. Core removed and casing filled with concrete. Casing removed with pressure on concrete.
Steel or iron shoes are commercially available for wood piles.
Driven same as straight shaft except when shell is partly removed. Concrete is poured for pedestal and rammed with core. Care must be used not to disturb adjacent piles with pedestal.

PILES

31. Eccentric Loading and Crooked Columns

The reduction in strength of a wooden column resulting from crooks, eccentric loading, or any other condition that will result in combined bending and compression is not so great as might be expected. Tests have shown that a timber when subjected to combined bending and compression, develops a higher stress at both the elastic limit and maximum load than when subjected to compression only. This does not imply that crooks and eccentricity should be without restriction, but it should relieve anxiety as to the influence of crooks such as those common in piling.

32. Driving of Piles as Affected by Seasoning

The usual conditions of service are such that a pile in place will be wet. However, because of the increased strength resulting from drying, seasoned piles either treated or untreated are likely to stand driving better than green or unseasoned ones. This is particularly true of treated piles. Tests have demonstrated that while the strength of green wood may be considerably reduced by treatment, treated wood, after thorough seasoning, may be but little weaker than untreated wood. Under the same drying conditions, however, untreated material loses moisture more rapidly than does treated material.

It is often necessary for piles to be cut, treated, and placed within so short a period that there is no time for the strength to be affected by drying. In such cases, special care in driving is advisable.

33. Decay Resistance and Preservative Treatment of Piling

Piles are cut from small trees which, in the majority of species, have rather wide sapwood and consequently low decay resistance. High natural decay resistance will be found only when the piles have thin sapwood and are of species that have decay-resistant heartwood. See the Chapter on Wood Preservation.

Wood that remains completely submerged in water does not decay. Decay resistance is not necessary in piling so used, but it is necessary to protect any part of the piling that may extend above the permanent water level. When piles that support the foundations of bridges or buildings are to be cut off above the permanent water level, they should, as a safety precaution, be pressure creosoted by the empty-cell process, with not less than 12 pounds of creosote per cubic foot. The untreated surfaces exposed at the cut-offs should also be given protection, as covered in the Chapter on Wood Preservation.

Piling driven into earth that is not constantly wet is subject to about the service conditions as apply to poles, has similar life, and requires similar protection.

Piling used in salt water is, of course, subject to destruction by marine borers even though it does not decay below the water line.

34. Spacing of Piling

The usual spacing of piling is from 3 to 4 feet, center to center, but the spacing may be increased if desired. The closest spacing allowable would be approximately 2 feet, center to center. Closer spacing than 2 feet center to center will often cause the piles which have previously been driven to crowd up out of the ground.

35. Depth of Piling

The plans and specifications sometimes specify the depth to which piles are to be driven, but more often state that piles will be driven to "refusal." The word, "refusal", is very indefinite, and should be defined in terms of known quantities. The pile may be down to refusal if a two-ton hammer, falling 15 feet, does not increase the penetration more than 1/2" during four or five blows. This rule should not be followed literally because under certain conditions a pile will remain stationary for a number of blows and then sink several inches under successive blows.

If, after refusing to move for a number of blows, the pile moves rapidly, there is a good indication of breakage or brooming of the end. A broken or broomed pile will cause settlement of the foundation above it, and should be removed, or strengthened by the addition of another pile beside it.

36. Equipment for Driving Piling

The two types of equipment generally used for driving piles are the drop hammer and the steam hammer.

A. Driving Wooden Piles with a Drop Hammer

Piles should be driven to an even bearing which is determined by the penetration under the last 4 or 5 blows of the hammer as mentioned above. The usual method of driving piling for support of buildings is by a succession of blows given with a large block of cast iron or steel called a hammer or driving head, which slides up and down between the uprights of a machine called a pile driver. This machine is placed over the piles so that the hammer descends squarely on the head or large end of the pile. When the hammer is raised by a steam-driven or gas-driven engine, operating with cable drums and controls to lift the hammer in the frame of the pile driver, the cable is simply allowed to unreel from a free running drum. Where capstans and horse-driven methods are used, the hammer is lifted to its maximum height and is then automatically dropped by a latch or lever which releases the cable and lets the hammer fall directly upon the head of the pile. The usual weight of a hammer used for driving piles for building foundations is from 1,500 to 2,500 lbs. and the fall will vary from 5 to 20 feet, usually averaging 15 feet.

Hammers will sometimes weigh up to 4,000 lbs. or more.

B. Driving Wooden Piles with Steam Hammers

Steam hammers will drive more piles in a day and with less damage than drop hammers. This type of hammer delivers short, quick blows, averaging 60 to 70 a minute, and seems to jar the piles down because the short interval between blows does not give time for the soil to settle around them. Steam hammer equipment usually requires some form of derrick for handling.

The piles must be kept plumb when they are driven by either of the two methods. Whenever a pile refuses to sink under several blows before reaching the average test depth, it should be cut off and another pile driven beside it. When several piles have been driven to a depth of 30 feet or more and refuse to sink more than 1/2" under five blows of a 1,200 lb. hammer falling 15 feet, it is usually useless to try to drive them farther, as additional blows will only result in brooming or crushing the heads. It is good practice to use metal driving shoes on the bottoms of piles when difficulties are encountered in driving.

37. Jetting of Piles

In many instances the use of a jet of water is the most economical method of pile-driving. This is especially true if the piles are to be driven in clear sand, mud or soft clay. It must be clearly understood that a stream of water will not move gravel, gravelly sand or hard clay.

In water-jet pile driving, a jet of water is discharged below the point of the pile to loosen the soil and allow the pile to settle in place by its own weight or with light blows of a hammer. The simplest form of jet is a hose or pipe which is attached to the pile for its full length. A continuous stream of water is forced to the toe of the pile, under pressure. This method uses a large amount of water because there is usually no constriction of the lower end of the pipe, and provision must be made to take care of the overflow.

A better type of jet has a nozzle at the lower end. The main length of pipe may have a diameter from 3/4" to 2". The nozzle should reduce the opening to approximately 3/4". This reduction will increase the velocity and force a stronger stream against the soil. Satisfactory jets can be made by using reducing nipples until the desired opening is reached. Jets may be operated successfully under city water pressure but work more efficiently if the pressure is increased by the use of a pump.

38. Pulling the Piles

When driving is extremely hard and there is a question as to the condition of the driven piles, there is but one way of arriving at the correct answer. That way is by the removal of the piling in question. The condition of the piles will disclose whether an obstruction has been stopping them.

39. Capping of Wooden Piles

For foundation supports the tops of piles should be cut off at, or below, the low water mark to prevent decay. The low water mark is the point of continuous saturation of the soil with water. Piles should be capped, either with large stone blocks, concrete blocks, or with a timber or steel grillage.

Concrete capping is most generally used, and the method of doing the work is as follows: Excavate 6" to 10" below the top of the pile and one foot outside the pile. Place the concrete around the pile and to a point about 3" above the top. At this point, reinforcing is run in both directions and more concrete is added until the required thickness of the cap is reached. Caps are usually about 18" thick. This, however, depends upon the number and spacing of the piles in the group and the designed requirements for bearing shear. It is upon the cap that the foundation for the columns and walls is placed.

When timbers are used for grillages, they should be at least 10" x 10" in cross-section and should have sufficient transverse strength to sustain the load from center to center of the piles. They should be laid longitudinally on top of the piles and fastened to them by means of drift bolts or pins. Holes should be drilled through the timbers and the drift pin should be driven through these holes into the piling at least one foot. When this type of timber grillage is used, it should be kept below the lowest recorded water line; otherwise, it will rot and allow the building or structure to settle.

References:

Wood Handbook - Forest Products Laboratory

CHAPTER VI - WOOD PRESERVATION

40. Preservatives

Wood preservatives fall in three general classes:

1. Those of an oily nature, which are relatively insoluble in water.

2. Those in which certain salts are injected into wood in the form of water solutions.

3. Those in which the toxic constituent is carried in some volatile solvent other than water.

A. Coal-tar Creosote

In coal-tar distillation, the portion between the light oils and the pitch residue is the creosote used for wood preserving purposes. Coal-tar creosote is a black or brownish oil whose character is influenced by the kind of tar used, the method of distillation, the degree to which the distillation is carried, and the portion of the distillate that is included in the creosote fraction.

Although the characters of the various coal-tar creosotes may vary to a considerable extent, they all give good service. Any reasonably good grade of coal-tar creosote gives satisfactory results in decay prevention.

It is the most important and most generally useful wood preservative. Its advantages are (1) its toxicity to wood-destroying fungi and insects, (2) its relative insolubility in water, and its low volatility, which impart to it a great degree of permanence under the most varied conditions, (3) its ease of application, (4) its uniform depth of penetration, (5) its general availability and relatively low cost.

Although there is no better preservative than coal-tar creosote for structural timbers in general out-door service, it has certain properties that render it useless for some types of construction. Freshly creosoted timber can be ignited easily and will burn readily, producing a dense smoke.

After some months of seasoning, the most volatile parts of the oil disappear from the surface and the creosote-treated wood is but little easier to ignite than untreated wood. Engineers differ as to the fire hazard involved in the use of well seasoned, creosoted timber. Because of the difference of opinion, there appears to be some justification for a recommendation that treated wood be protected from fire unless some other preservative than creosote is used.

The odor of creosoted wood is unpleasant and its use may be objectionable in dwellings. In spite of the objection to its odor, it is widely used for sills and foundation timber and for floor sleepers embedded in or resting on concrete.

The use of creosote on finish lumber is not satisfactory where appearance and paint receptivity are of major importance.

B. Water-Gas-Tar Creosote

Water-gas-tar creosote is made from water-gas tar in much the same way that coal-tar creosote is made from coal tar. Water-gas tar is the residue remaining after the manufacture of water gas from petroleum oils. It is a petroleum product and not a coal product, and the composition of both the water-gas tar and its creosote are different from the respective coal products. Water-gas-tar creosote is not so toxic or so generally effective as coal-tar creosote, but it has a good preservative value. Aside from lower toxicity, its advantages and disadvantages are generally similar to those of the coal-tar product.

C. Wood-Tar-Creosote

Wood-tar creosotes are made by the distillation of wood-tar. They are not used extensively for wood preservation because they have never been produced in sufficiently large quantities of satisfactory and uniform quality and price to attract the attention of large consumers. Their effectiveness in comparison with other creosotes has not been definitely determined.

D. Tar

Highly viscuous tars cannot be advantageously used alone because of the small depth of penetration. Surface coatings of tar have been found to be of little value. Certain tars, when mixed with other materials, have given good results in service tests.

It is common practice to mix coal tar or water-gas tar with coal-tar creosote. The proportion of tar is sometimes as high as 50 per cent. If clean tars are used, and they do not interfere too seriously with penetration, such solutions are very effective. Tar solutions are cheaper than straight creosote and should give better protection against checking of the wood. They leave the wood less clean than creosote and penetrate less easily.

E. Petroleum Oils

Many experiments have been made with crude petroleum, "topped" petroleum, fuel oil, and waste crankcase oil as wood preservatives. Experience has demonstrated that chemically unchanged petroleum oils used alone are not to be relied upon. Occasionally, good results have been obtained, but in most cases complete failure has resulted.

Petroleum is extensively used as a diluent for creosote in the treatment of railway ties, the most common proportion being about 50 per cent of each. The mixture is less toxic than straight creosote, but if a sufficient amount is injected, satisfactory protection from decay may be expected. The advantages and disadvantages of the mixture in comparison with straight creosote are as stated for tar solutions, except that tar solutions have higher toxicities than petroleum mixtures.

F. Zinc Chloride

Zinc chloride is the water-soluble wood preservative most extensively used in the United States. The principal advantages of this salt are relative cheapness, general availability, uniformity of quality, cleanliness, paint receptivity of the treated wood, lack of odor, ease of shipment and lack of fire hazard. The chief disadvantage is its solubility in water, which permits it to leach out of wood when in contact with wet soil or during periodic wetting. The water that is injected with it temporarily adds considerably to the weight of the wood. In order to avoid shrinkage troubles, the wood must be dried out before it is used under conditions where shrinkage would be objectionable.

Zinc chloride has a slight effect in reducing inflammability when it is injected into wood in the usual quantity of about one-half to 1 pound of dry salt per cubic foot.

Zinc chloride treated wood is finding increasing use in the construction of buildings. It is especially desirable for the roof planking of factory buildings where the high relative humidity favors the rapid decay of the roofs. The fact that the net weight of the wood is not greatly increased by the treatment, that the treated wood is clean and paintable and that it is to a slight extent fire resistant, favors its use in such places.

The following zinc chloride specification of the American Wood Preservers Association is accepted for government use and is the one generally used in the purchase of zinc chloride for wood preserving purposes:

> "The zinc chloride shall be acid free and shall not contain more than 0.1 per cent iron. Fused or solid zinc chloride shall contain at least 94 per cent chloride of zinc. Concentrated zinc chloride solution shall contain at least 50 per cent chloride of zinc."

Concentrated zinc chloride is diluted with water to solutions of about 3 to 5 per cent strength for use in treating wood.

G. Sodium Fluoride

Sodium fluoride, in a mixture with other materials, has been used to some extent in Europe for preserving wood, especially mine timbers. In the United States it has been used alone experimentally for preserving railway ties, mine ties and mine timbers since 1914. It has also been used to some extent commercially in the treatment of factory roof timbers. The evidence thus far available indicates that it is a good wood preservative. For the most part, its advantages and disadvantages are similar to those of zinc chloride. The chief disadvantage is its relatively high price, which in recent years has been, roughly, one and one-half times that of zinc chloride. It can be precipitated by salts of calcium and thus in time be made ineffective in soils having a high lime content. Sodium fluoride is an important ingredient of several proprietary or patented preservatives.

H. Arsenic

Arsenic in various forms, either alone or mixed with other substances, has been used as a wood preservative for a number of years. A considerable number of arsenic treated poles, ties and other timbers are now in service. It is still too early to tell how effective the various forms and combinations of arsenic will be, but some of them have given promising results thus far. Arsenic salts are toxic to many fungi, but there are some fungi that, under conditions favorable to their growth, can live in the presence of arsenic salts and even convert them slowly into poisonous gas. Certain investigators believe that the small amounts of arsenical gases that may be produced in this way in a building are dangerous to the health of the occupants. Others do not share this belief. The question is still unsettled, but should be given consideration in connection with the use of arsenical preservative in any place where there is insufficient ventilation to carry away the gases as rapidly as they may be produced.

I. Mercuric Chloride

Mercuric chloride or corrosive sublimate is very effective in prolonging the life of wood, but its relatively high price, its extremely poisonous character, and its corrosive action against metal are against it. Although it is still used to some extent in Europe, either alone or mixed with sodium fluoride, and has been used to a slight extent for many years in the United States, it will probably never be extensively used as a wood preservative.

J. Proprietary Preservatives

Many preservatives are sold under various trade names. Some of them are ordinary coal tar creosotes that have been modified slightly by taking out some of the solid ingredients. Others have had the higher fractions removed, giving them a higher boiling point than the ordinary run of creosote. In the main, preservatives derived from coal-tar creosote are good and may be used with assurance. Their economical use depends upon their convenience and their cost as compared with coal-tar creosote or zinc chloride.

Other proprietary preservatives contain wood-tar products or other oils. Their value is not so well established, but no doubt some of them have value.

In a third group are preservatives combined with water. Their value depends on the materials of which they are composed, but several appear to be giving promising results. The purchaser of a preservative of this kind should insist upon knowing its ingredients and their proportions.

A fourth group of proprietary preservatives is being developed in which the toxic chemical is carried into the wood in a colorless solvent other than water. Preservatives of this kind are particularly useful in the treatment of flooring, furniture, millwork exposed to fungus and termite attacks, window sashes and frames, and automobile woodwork, where clean treatment without swelling is required. Evidence on the degree of effectiveness of these preservatives is very incomplete and several of them are of very recent origin. As a group, they promise to be useful. The user of such preservatives should insist upon knowing the nature and amount of the effective chemicals in the mixture.

The literature advertising some of the proprietary preservatives frequently contains extravagant claims as to their properties and their effectiveness. Obviously, such claims should be greatly discounted. There are very few, if any, proprietary preservatives for general use, regardless of price, that have yet shown themselves to be better or more generally satisfactory than straight coal-tar creosote and zinc chloride in their respective classes.

41. Preparing Timber for Treatment

For satisfactory results with any treating process the timber must be sound and suitably prepared for treatment. Preservatives will not make weak timber strong, nor will they restore the strength of timber that has been partially destroyed by decay. Further, except in material of small dimensions, the preservative and the heat of the treating process cannot be expected to always kill all fungus growth in an infected or partially decayed stick. Hence, any fungus present may continue to grow after treatment, perhaps destroying completely the unpenetrated interior of the timber.

A. Peeling

The peeling of round or slabbed timber is necessary to enable it to season quickly enough to avoid decay and insect damage and to permit the entrance of preservatives. Strips of even the thin inner bark may prevent penetration. Patches of bark left on during treatment will fall off in time and expose the untreated wood. This permits decay to reach the interior of the timber. Careful peeling is especially important for wood that is to receive an inexpensive surface treatment. In the more thorough processes of treating, small strips of bark are not quite so harmful.

B. Seasoning

Applying surface treatments of preservative oils to green or wet wood is practically useless, because preservatives so applied cannot penetrate wood that is already full of water. Plants which treat timber by pressure processes can use artificial means of conditioning green timber to make it more absorptive and thus avoid the long delay incident to air seasoning. Air seasoning, despite the greater time, labor and storage space required, is the most widely used method of conditioning.

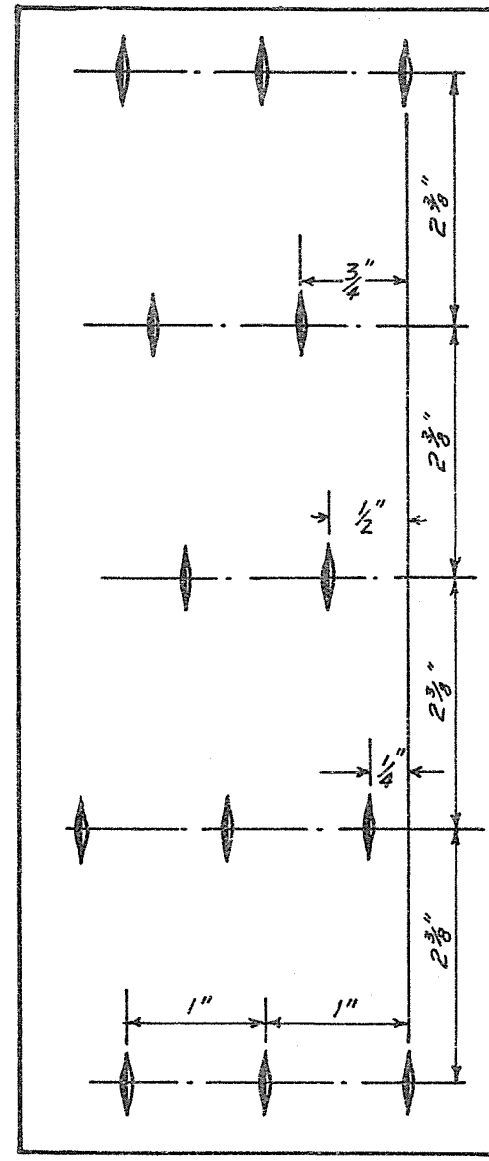
The amount of air seasoning required will depend on climate, the location and condition of the seasoning yard, the methods of piling, the season of the year, and the size, species, and character of the timbers. It is not uncommon in commercial practice to season railway ties and larger timbers for 8 to 12 months if conditions permit and if the timber can be kept that long under local conditions, without deterioration. A great deal can be accomplished even with large pieces in 3 to 6 months of good seasoning weather. Small pieces season more quickly than large pieces and sapwood seasons more quickly than heartwood. The most satisfactory seasoning practice for any specific case will depend on the individual drying conditions and the preservative treatment to be used. It must be determined by experience.

It is not necessary that the timber be seasoned to a uniform moisture content throughout, but the part that is to be penetrated by the preservative must have enough water removed to make room for the preservative to enter. The exact moisture content at which air-seasoned wood takes treatment best has not been determined.

C. Incising

Wood that is resistant to penetration by preservative is sometimes incised before treatment to permit deeper and more uniform penetration. Sawed or hewed material is passed through a machine having horizontal and vertical rollers equipped with teeth than sink into the wood to a predetermined depth, usually three-eights to three-fourths of an inch. The teeth are spaced so as to give the desired distribution of preservative with the minimum number of incisions. A machine of different design is required for incising the butts of poles. Tools are available for incising by hand methods.

The effectiveness of incising depends on the fact that preservatives usually penetrate into wood much farther in a longitudinal direction than in a direction perpendicular to the face of the stick. The incisions expose end-grain surfaces and thus permit longitudinal penetration. Incising is practiced chiefly on Douglas Fir ties and timber and on cedar poles, but is employed to some extent on poles, posts and ties of other species. It is especially effective in improving penetration in the heartwood areas of sawed or hewed surfaces.



The depth of the incisions shall be such as to secure a uniform penetration of preservative conforming to the following schedule:

Sizes	Treatment - Lbs per Cubic Foot of wood.					
	6#	8#	10#	12#	14#	16#
3 x 12		1/4"	5/16"	3/8"	7/16"	1/2"
4 x 12		5/16"	3/8"	7/16"	1/2"	9/16"
6 x 8	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"
8 x 10	3/8"	7/16"	1/2"	9/16"	5/8"	3/4"
10 x 12	7/16"	1/2"	9/16"	5/8"	3/4"	3/4"
12 x 12 + Larger	1/2"	9/16"	5/8"	3/4"	3/4"	3/4"

INCISING

D. Cutting and Framing

All cutting, framing and boring of holes should be done before treatment. Cutting into the wood in any way after treatment will expose the untreated interior of the timber and permit ready access of decay fungi. Railroads and other large users now follow the practice of framing before treatment and find it not only practical but economical.

42. Pressure Treatment

The most effective method of treating wood with preservatives is by a pressure process. The timber to be treated is placed on steel cars and run into a long steel cylinder, which is then closed and filled with preservative. Pressure is applied to force the preservative into the wood until the desired amount has been absorbed. Two principal types of pressure treatment, the full-cell and the empty-cell, are in common use.

A. Full-cell Process

The full-cell or Bethell process is widely used with preservatives in a water solution or with oils when the retention of a maximum volume of preservative is desired. It is not so satisfactory with oils when limited absorptions are specified. Limited absorptions of preservatives in water are usually obtained by regulating the strength of the solution rather than by limiting the volume of the preservative injected, hence, the full-cell treatment is very suitable for these preservatives.

B. Empty-cell Process

The object of the empty-cell treatment is to obtain deep penetration with a relatively low net retention of preservative. Empty cell treatments should be used with preservative oils in preference to full-cell treatment, except when maximum absorptions are desired. They are not important for injecting water solutions except when it is desired to keep the water absorption as low as possible by using solutions of greater strength than are usually used. Two empty-cell treatments are commonly employed, both of which make use of the expansive force of compressed air to drive out part of the preservative absorbed during the pressure period.

C. Specifications

Specifications covering the details of treatment by various pressure processes and by the hot-and-cold bath process for poles have been prepared by the American Wood Preservers Association. These specifications are in use by the Federal Government and by some States. They have proven fairly satisfactory, but are capable of improvement. The wood preservation specifications of the American Railway Engineering Association are similar to those of the American Wood Preservers' Association.

D. Treating Pressures and Preservative Temperatures

The pressures used in the full-cell and Lowry (or empty-cell without initial air) treatments, vary from about 100 to 200 pounds per square inch, depending on the ease with which the wood takes the treatment, but are most commonly about 150 to 175 pounds per square inch. Pressures applied in the Rueping (or empty-cell with initial air) treatment, are usually between 150 and 200 pounds per square inch, depending on the preliminary air pressure employed.

Specifications commonly require that the temperature of the preservative during the pressure period shall be not less than 160° nor more than 200° F. and shall average at least 180°. Since high temperatures are much more effective than low temperatures in treating resistant wood, better penetration would be obtained by using temperatures between 190° and 200°. This applies to both preservative oils and water solutions.

E. Absorption and Penetration

In the full-cell process, the amount of oil usually injected into structural timber for land use, varies from 10 to 16 pounds per cubic foot. Piling which is to be used in salt water in which marine borers are active, should be treated practically to refusal. This may mean 20 pounds or more per cubic foot for southern yellow pine having thick sapwood, and from 14 to 16 pounds per cubic foot for Douglas Fir. In the empty-cell processes, absorptions of 6 to 12 pounds per cubic foot are commonly used in lumber, ties and timbers. The amount depends upon the species, the proportion of sapwood, and the conditions under which the timber is to be used. The absorption in material that is largely heartwood and of small cross section should be greater than the absorption in larger sizes, in order to obtain equivalent protection. This is because of the greater proportion of surface area to volume in the smaller sizes. More than twice as much absorption per cubic foot may be required in very small sizes to obtain a penetration as good as that in large timbers. For unusually large heartwood timbers, the absorption per cubic foot may have to be reduced. Sapwood timbers, or species that have easily treated heartwood should have higher absorptions than timbers consisting largely of resistant heartwood.

The minimum absorptions of creosote and of zinc chloride required in timber of various kinds for use by the Federal Government (U. S. Federal Specifications Board) are shown in the Wood Handbook prepared by the Forest Products Laboratory. Higher absorptions are usually required for best results, especially in material that is largely sapwood.

Penetrations vary widely, even in pressure-treated material. In most species, heartwood is more difficult to penetrate than sapwood. There are also great differences between species in the degree to which heartwood may be penetrated. The heartwood of white oak, red gum and mountain-region Douglas Fir is practically impenetrable by commercial treating processes. Penetrations in unincised heart faces of these species are sometimes as deep as one-fourth inch, but

are usually not more than one-sixteenth inch. Experience has shown that even these slight penetrations have some value. The heartwood of coast-region Douglas Fir, southern yellow pine, and various hardwoods, is quite resistant but can be made to take penetrations from one-fourth to one-half inch and sometimes considerably more. Incising aids in the treatment of most of these species. The heartwood of black gum, ponderosa pine and most red oaks and the light-colored heartwood in beech, can be penetrated deeply.

An attempt should be made to obtain a full penetration of sapwood in all pressure treatments. This can always be accomplished in small pieces. With skillful treatment, deep penetration may be obtained in piling, poles, ties and structural timbers. Complete penetration of sapwood in every piece is seldom possible when treating large pieces of round material having thick sapwood, such as southern pine poles and piling. Much difficulty is experienced in obtaining complete penetration of sapwood when the absorption is low. Better penetrations are obtained for a given absorption by the empty-cell treatment than by the full-cell treatment.

43. Handling Timber After Treatment

Treated timber should be handled with care to avoid breaking through the treated portion. The use of pikes, cant hooks, picks, tongs, or other pointed tools that dig deeply into the wood should be prohibited. Spikes or dogs may be driven into piling near the point and near the butt when necessary for forming log booms, but they should never be driven into the part of the pile that will be exposed in service. The handling of heavy loads of lumber or sawed timber in rope or cable slings may crush the corners of the outside pieces. Breakage or deep abrasions may also result from throwing the material or dropping it any considerable distance. When damage has resulted through carelessness or otherwise, the exposed places should be re-treated as thoroughly as conditions permit.

44. Field Treatment of Cut Surfaces

Although it is highly undesirable to cut into wood after it is treated, this cannot always be avoided. When cutting is necessary, the damage may be partly overcome in timber for land or fresh-water use by thoroughly brushing the cut surfaces with coal-tar creosote. Two coats of hot oil should be applied, but a cold application is better than none at all. The brush coating of cut surfaces gives little protection against marine borers. When wood has been treated with water-soluble preservatives, a strong solution of the preservative used should be applied. When treating the exposed surfaces of pile heads, the brush treatment should be given with great care and thoroughness. A coat of pitch, asphalt or similar material should be applied over the creosote. The pile head should then be covered by some protective sheet material such as metal, roofing felt, or a saturated fabric. The cover material should be brought down the sides far enough to prevent damage to the top treatment.

A small hand pump now on the market may be used to force creosote into bolt holes which are bored after the wood is treated.

45. Inspection

A. Grade and Quality

It is desirable to inspect the timber for quality before it is treated. When it is impractical to make an inspection previous to treatment, the purchaser can inspect for quality after treatment. If this is to be done, the fact should be made clear in the purchase order.

B. Absorption

After treatment, it is impractical to determine by analysis or inspection of the treated wood, whether the specified absorption has been injected. This is because the non-uniform distribution of preservative throughout the length of the pieces affords no way to obtain a correct average sample from a charge of treated timber without destroying most of it. The purchaser must accept the statements or affidavits of the treating-plant operator or must have an inspector at the treating plant to observe the treatments and insure compliance with the specifications. Intelligent inspection at the treating plant is welcomed by plant operators. Railroad companies and other corporations that purchase large quanitites of treated timber usually maintain their own inspection service. Commercial inspection and consulting service is available for those purchasers who are able to pay an inspection fee, but who do not use enough treated timber to justify hiring inspectors of their own.

C. Penetration

Penetration measurements should be made at the treating plant if inspection service is provided, but can be made by the purchaser at any time after the timber has been treated. They give about the only measure of the thoroughness of treatment when professional inspection service is not available. Rejection of treated timber for insufficient penetration may be difficult to enforce, however, unless this point is definitely covered in the specifications or there is a previous agreement with the plant operator on the minimum and average penetration requirements.

The depth of penetration of creosote and other dark-colored preservatives can be determined directly by observing a boring removed by an increment borer. The borings should be taken at a distance of several feet from the ends of the piece in order to avoid the unrepresentative portions that are completely treated by end penetration. The boring should be made in poles and posts at the point where the ground line will be when they are in service. Since the preservative oil has a tendency to creep over cut surfaces, the boring should be split lengthwise, and the observation should be made promptly. Holes made for penetration measurements should be tightly plugged with a thoroughly treated wooden plug. Since penetration may be irregular, a single boring is not necessarily a correct indication of average penetration in the timber bored or in the other timbers in the charge.

The penetration of preservatives that are practically colorless must be determined by chemical dips or sprays that show the penetration by color reactions. The penetration of zinc chloride is determined as follows: Prepare separately a 1 per cent solution of potassium ferricyanide, a 1 per cent solution of potassium iodide, and a 5 per cent solution of soluble starch. In making the starch solution, boil until the starch is thoroughly dissolved, or the reaction will be unsatisfactory. The starch solution should not be allowed to sour before use. The wood to be tested should be reasonably dry. Mix 10 cubic centimeters of each of the three solutions, and, with a good atomizer, spray the mixture evenly on a freshly cut cross-section of the wood. The treated portion will at once turn dark blue, while the untreated portion will retain its original color. The color will fade with time unless renewed.

Other chemical mixtures have been developed by the promoters of proprietary preservatives for disclosing the penetration of their respective preservatives.

46. Effect of Treatment on Strength

Creosotes, creosote-tar mixtures, creosote-petroleum mixtures and the 2% to 5% solutions of zinc chloride commonly used, have no chemical influence upon wood that effects its strength. Treated timber can be given working stresses as high as those of untreated naturally durable wood under the same conditions of use.

Wood preservatives are not harmful in themselves, but the treatment necessary to inject them into the wood may result in a considerable loss of strength and stiffness. Green wood may be seriously reduced in strength if extreme temperatures or heating periods are employed while they are being conditioned for the injection of preservatives. Consequently, care should be used to keep the temperature as low, and the duration of the conditioning treatment as short, as is consistent with satisfactory absorption and penetration of the preservative. A gauge pressure of 20 pounds, or approximately 259° F., is sufficiently high for steam conditioning. No advantage is known to result from higher pressures, and the resulting higher temperatures are much more likely to damage the wood. The maximum termperature employed in boiling under the vacuum process is usually less than 210° F. The effect of temperature on strength is influenced by such factors as species of wood and the size and moisture condition of the timbers treated. The loss in strength increases with the moisture content and with the size of the timber.

The use of pressures greater than 175 pounds in injecting preservatives into wood that is soft from long heating is likely to cause severe end checking and collapse. Considerably higher pressure can be used if the wood has been heated for only a short time. Woods of low density are more subject to injury from high pressures than woods of high density.

47. Non-Pressure Treatment

In general, the application of preservatives by non-pressure methods is not so effective as by pressure methods. They should be employed only when it is impractical to use pressure-treated material.

A. Hot and Cold Bath Process

The hot and cold bath treatment is the most effective of the non-pressure processes, and the thoroughness of the treatment obtained most nearly approaches that of the pressure processes. The treatment may be accomplished in either of the following ways:

(1) By transferring the wood at the proper time from a tank of hot oil to a tank of cold oil.

(2) By draining the hot preservative from a single tank and quickly filling it with cold preservative.

(3) By shutting off the heat at the proper time and allowing the wood and the hot preservative to cool together.

The principle involved is that during the hot bath the heating causes the air and moisture in the wood to expand. When the cooling takes place, the air and the water vapor in the wood contract and a partial vacuum is thus created, which draws some of the preservative into the wood. Little absorption of preservative takes place during the hot bath, except in a few woods that are exceptionally easy to treat.

The chief use of the hot and cold bath process has been in treating the butts of posts and poles. The process is useful for lumber or timbers when circumstances do not permit the more effective pressure treatments. Coal-tar creosote is the most suitable preservative for posts and poles, but water solutions, such as zinc chloride may be used if proper care is taken to keep the solution at uniform strength.

Hot-bath temperatures up to 230° F. may be used with coal-tar creosote. This is the temperature used commercially in the butt treatment of cedar poles. Higher temperatures may give better penetrations, but if the temperature is too high, a considerable percentage of the oil may be lost by evaporation. This is especially true if a creosote with a relatively low boiling range is used. In the cold bath a temperature of approximately 100° F. is about right. This temperature keeps the oil fluid, but much cooler than the hot bath. If the oil is not sufficiently fluid at 100° F., the temperature of the cold bath should be increased.

The length of both baths must be governed by the demand for speed and the ease with which the timber takes treatment. A hot bath of 2 or 3 hours and a cold bath of like duration will probably

be sufficient for well-seasoned timber that is moderately easy to treat. Large sizes require longer heating than small sizes. The object of the coal-tar creosote treatment is to obtain as deep a penetration as possible with the use of a minimum amount of oil. If the penetration is not sufficient, the length of time in the hot or the cold bath should be increased. If the penetration is satisfactory, but too much oil is absorbed or the material drips too much after treatment, the cold bath should be shortened or a supplementary hot bath applied after the cold bath. The lengths of the baths will vary with the character and the condition of the timber and must be determined by trial. The penetration cannot always be controlled at will by manipulating the treating conditions. Some woods are highly resistant to treatment and may permit a penetration of one-eighth inch or less, especially in heartwood faces. The sapwood of most species is less resistant to penetration than the heartwood and hence penetrations of one-fourth to 1 inch are often obtained.

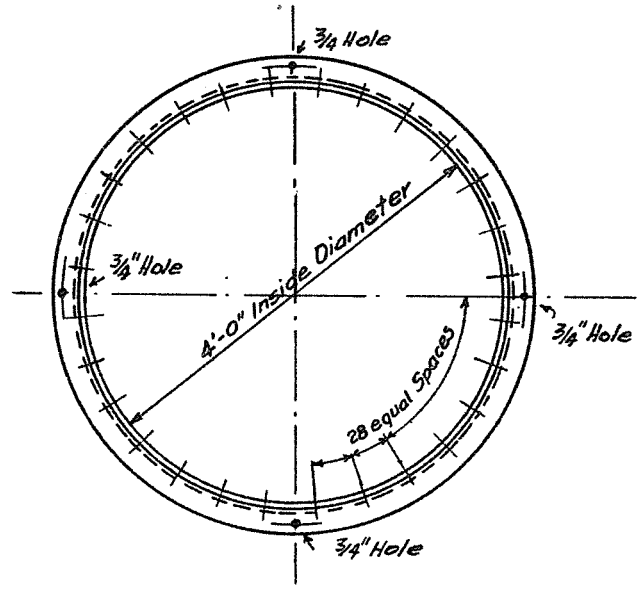
B. Steeping Process

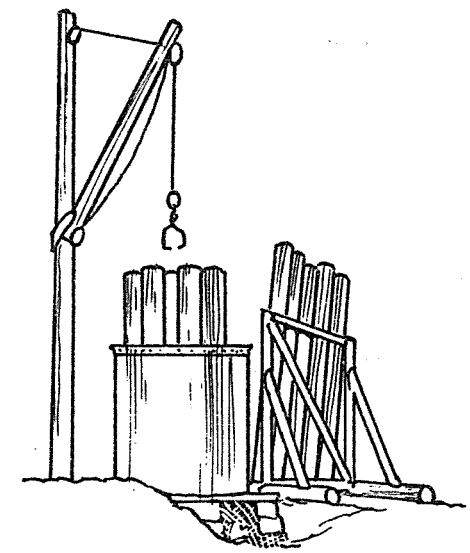
Although the steeping process is old and has been employed in Europe for many years, its use in the United States has not been extensive. Its usefulness is very limited. When mercuric chloride is employed as the preservative, the process is called the kyanizing or the kyan process. Zinc chloride and other water-soluble preservatives may also be used.

In treating by the steeping process, the timber is simply submerged in the unheated preservative solution and allowed to soak, usually for about a week. A longer soaking period would result in better absorption and penetration of the preservative, and when time is not an important factor, it is advisable to soak the timber for two weeks. When time is very limited, the timber can be removed from the solution after 2 or 3 days, and fairly good results may be expected. The penetrations obtained are likely to vary from as little as one-sixteenth of an inch to as much as 1 inch, depending upon the resistance of the wood being treated.

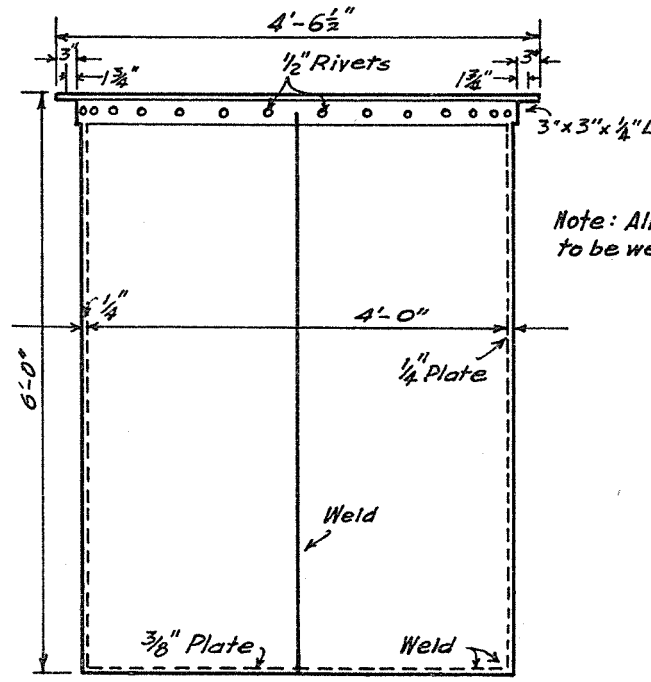
If the lumber to be treated has flat surfaces and is closely piled, the solution may not easily come into contact with all parts of each piece. It is important with all sawed material, to use stickers one-half inch or more in thickness between adjacent boards. When mercuric chloride is used, the tank must be made of a non-corroding material or must have special protection against corrosion.

A solution strength of about 1 percent is common with mercuric chloride. For zinc chloride a solution of about 5 per cent is recommended.



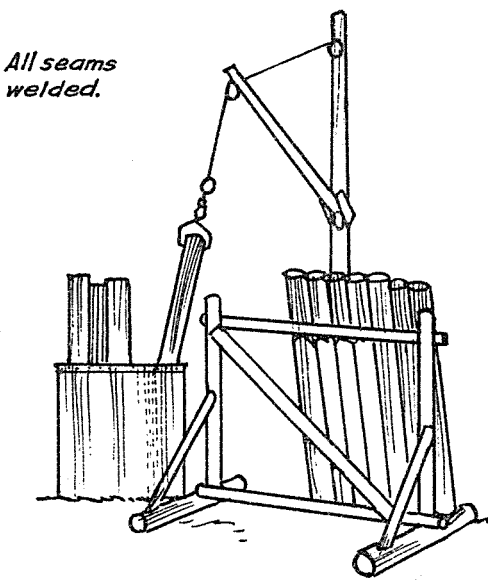


VIEWS OF TREATING PLANT

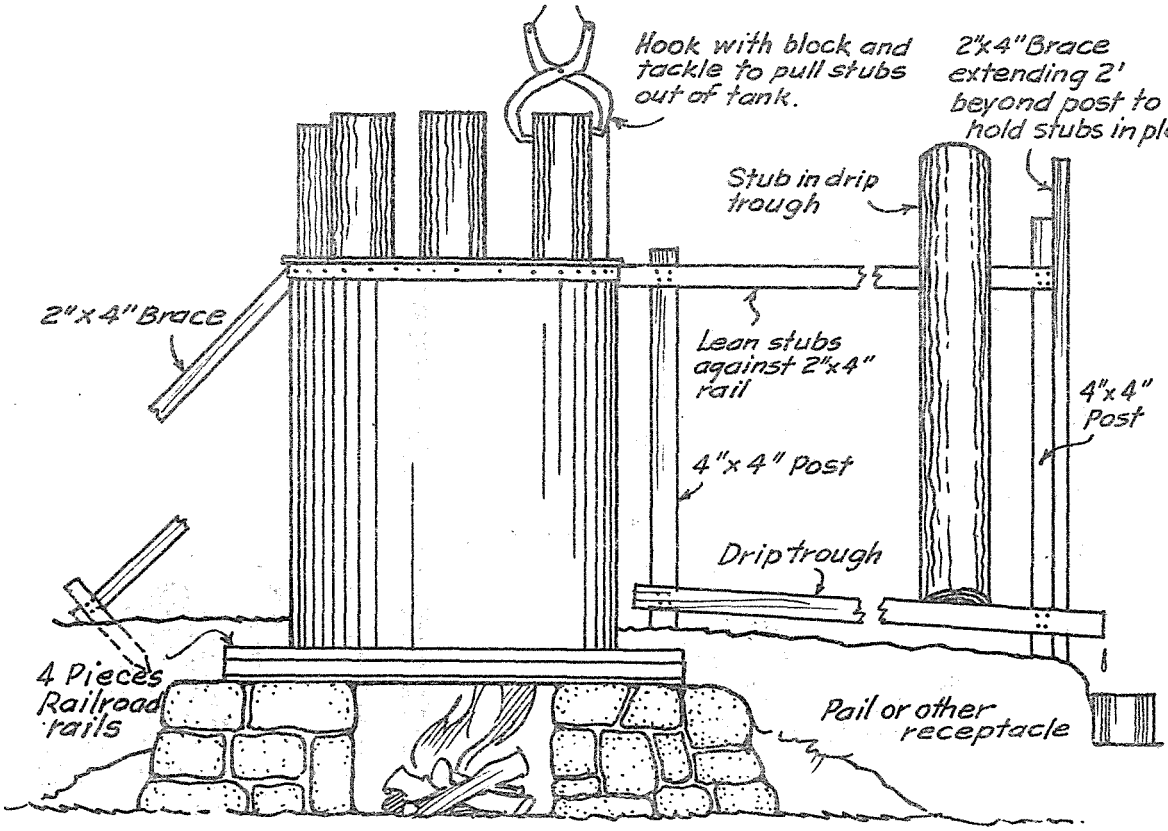


Note: All seams to be welded.

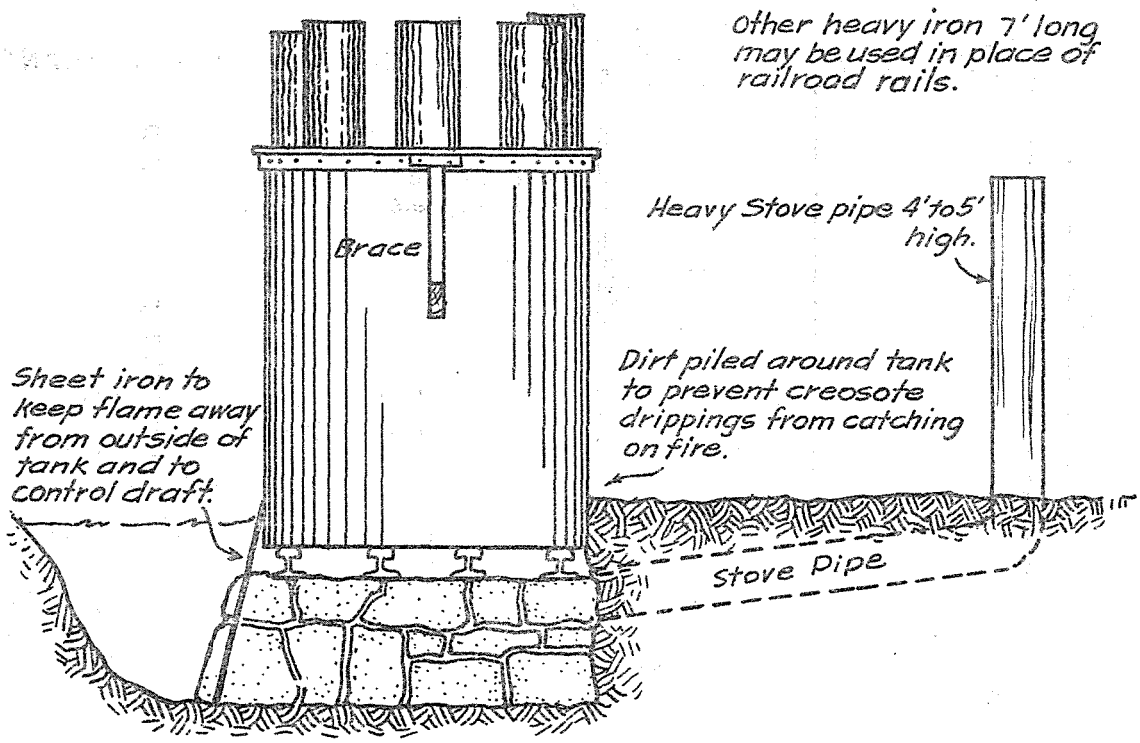
CREOSOTING STEEL TANK



TIMBER TREATING PLANT


Hook with block and tackle to pull stubs out of tank.
2"x4" Brace extending 2' beyond post to hold stubs in place.
Stub in drip trough
2"x4" Brace
Lean stubs against 2"x4" rail
4"x4" Post
4"x4" Post
Drip trough
4 Pieces Railroad rails
Pail or other receptacle

Other heavy iron 7' long may be used in place of railroad rails.


Brace
Heavy Stove pipe 4' to 5' high.
Sheet iron to keep flame away from outside of tank and to control draft.
Dirt piled around tank to prevent creosote drippings from catching on fire.
Stove Pipe

TIMBER TREATING PLANT

C. Dipping Process

The dipping process, which is used with creosote and similar preservatives, consists of submerging the wood in the hot preservative for from 5 to 15 minutes, and then removing it and allowing the excess oil to drain back into the tank. The temperature of the oil should be from 200° to 230° F., and the wood should be thoroughly seasoned and dry on the surface. A longer dipping period should be used in cold weather. Wood should not be dipped while it is covered with frost, snow or rain water because the water on the surface will interfere with the absorption of oil.

The effectiveness of the dipping treatment is limited and the process should not be used unless better methods are out of the question. The amount of oil absorbed will depend upon the timber and upon the length of the treating period. Ordinarily, it will be about 10 to 15 gallons per 1,000 square feet of surface. The penetration obtained in exceptional cases may be from one-eighth to one-fourth inch, but ordinarily it will be one-sixteenth inch or less. The dipping process gives assurance that all surfaces have been thoroughly coated with oil.

D. Brush Treatment and Spraying

The simplest and least effective treatment is the application of the preservative to the wood with a brush or a spray nozzle. Creosote and similar oils, preferably hot, are used in the treatment. Heating is sometimes inconvenient, and cold oil is applied. In such an event the creosote or oil that is selected should be thoroughly liquid when cold. The oil should be flooded over the wood, rather that merely painted upon it. Care should be taken to see that every check and depression in the wood is thoroughly filled with the preservative, since any exposed, untreated wood provides ready access for fungi. At least two coats should be applied, the second one afte the first has dried. This may require as much as 10 gallons of oil to 1,000 square feet of surface on rough lumber, but considerably less on surfaced lumber. The penetrations obtained will usually be less than one-sixteenth of an inch.

Brush treatment with water-soluble preservatives is not worthwhile for wood that is exposed to the weather or to water. It is less likely to be effective than creosote brush treatment.

The material given above on Wood Preservation has been taken largely from the section of "Wood Preservation", Wood Handbook, Fores Products Laboratory, Forest Service, United States Department of Agriculture.

CHAPTER VII - PROTECTION AGAINST WOOD-DESTROYING ORGANISMS

48. Mold, Stain and Decay

Mold or decay which appears in lumber may generally be traced to lack of proper precautions in yarding the logs and in piling, storing, and handling the sawed material.

Molds, stains, and decays in wood are caused by fungi, which are microscopic plants that live on organic material. Wood is the proper food supply for some fungi. Their growth is dependent upon suitable surroundings of mild temperature and dampness, the latter being aggravated by sluggish circulation of air. Most decay occurs in wood containing moisture above the fiber saturation point. Wood that is continuously water-soaked or continuously dry will not decay.

A. Molds and Stains

Molds and stains, which are confined largely to the sapwood, are characterized by cottony or powdery surface growths of various colors. The discoloration caused by molds is largely superficial and is due for the most part to a surface growth which varies in color on white or light to black. Such blemishes are easily brushed or surfaced off.

Stains penetrate the sapwood and cannot be removed by surfacing. The discoloration of the wood occurs as specks, spots, streaks or patches of varying intensities of color. The term blue stain is applied because the color is usually bluish gray to black.

Stains should not be considered as a stage of decay, since staining fungi do not appreciably affect the wood substance. The strength of the wood is only slightly affected and the effect is usually confined to those properties that determine shock resistance.

Blue-stained stock is satisfactory for many uses in which appearance is not a limiting factor and in which conditions permit the use of sapwood. It is not entirely satisfactory for window sashes, for if the sash becomes sufficiently wet, the staining fungi may grow. The growing fungi may break through the paint and make the sash unsightly.

B. Decay

Under conditions that favor their growth, decay-producing or wood-destroying fungi may attack either heartwood or sapwood. This fungi attack causes a condition of the wood that is variously designated as decay, rot or dote. The fresh surface growths of decay fungi are usually fluffy or cottony. They may appear as fan-shaped

patches, strands, or rootlike structures, usually white or brown in color. The occurrence of fruiting bodies, which take the form of toadstools, brackets or crusts is evidence of interior disintegration of the wood. The microscopic strands of hyphae that permeate the wood use portions of the wood itself as food. Some wood-destroying fungi live largely on the cellulose, whereas others use the lignin more than the cellulose.

Certain wood-destroying fungi attack the heartwood of living trees, while others confine their activities to logs or manufactured products, such as sawed lumber, structural timbers, poles and ties. In living trees the sapwood is less subject to attack than the heartwood. The sapwood of logs or manufactured products decays more rapidly than the heartwood. This may be due to the more available food supply in the sapwood, or to the presence in the heartwood of certain extractives that are toxic to the fungus.

Incipient decay induced by some fungi is reflected immediately in pronounced weakening of the wood while other fungi produce only slight reduction in strength. In the later stages of decay, any wood-destroying fungus will cause a serious reduction in strength.

C. Control of Molds, Stains and Decay

Poles, piling, ties and similar products are peeled and piled on high, well-drained ground in the sun to speed up surface seasoning. This retards the development of molds, stains and decay, but often causes checking of the timber. The species of wood, the section of the country from which it comes, and the time of the year in which the seasoning is to be done, will all aid in determining the precautions necessary to prevent excess checking and obtain rapid seasoning.

Logs may be protected during the normal storage period by the use of antiseptic sprays and coatings applied to the ends and barked portions, if wood-infesting insects are not too prevalent.

Fungus defects in lumber may be prevented by quickly reducing the moisture content below 20 percent and then by keeping the wood dry. Freshly cut lumber may be treated with antiseptic solutions to prevent fungus infection during the seasoning period. Successful control by this method depends not only upon adequate treating practices, but also upon the proper subsequent handling of the material.

The best assurance of receiving lumber free from decay or stain is to deal with yards or mills that follow good seasoning practice. If lumber is to be used under conditions conducive to decay, it should be the heartwood of a naturally durable species or should be adequately treated with a good wood preservative.

49. Precautions against Decay in Buildings*

In order to avoid decay in buildings, the following points should be carefully considered when building or when making repairs due to decay:

Avoid the use of unseasoned and infected wood in construction. Unseasoned and infected wood may result from improper handling at the sawmill, retail yard, or after delivery on the job.

Buildings should be designed to avoid the possibility of the wood becoming damp enough to decay. Treated lumber or lumber of high natural decay resistance should be used where service conditions are such that the wood cannot be kept dry.

Foundation timber, posts, steps, porches or other wood parts of a building should not be placed in direct contact with the soil unless they are of treated wood or of the heartwood of a naturally durable species.

The use of treated wood or the heartwood of a naturally durable species is advisable for the ground floor if sufficient ventilation cannot be provided to keep the wood dry.

Decay in a building is often traceable to wood concrete forms, stakes, debris or old stumps left under a building during construction.

Wood flooring should be protected with a preservative when it is to be laid over concrete through which it can absorb moisture from the ground. It is especially important that fresh concrete be thoroughly dried before wood floors are laid over it.

The growth of decay organisms may be caused by leaks in roofs, around doors and windows and in plumbing. Such leaks should be repaired immediately.

Condensation water may accumulate in the lower rails of window sash in cold weather and provide favorable conditions for the growth of stain and decay-producing fungi. The use of storm windows reduces the amount of condensation and is effective in controlling stain and decay. The use of durable heartwood or treated lumber also helps to prevent decay.

*Decay Resistance in Woods for Window Sash and Frames is covered in a Bulletin by G. M. Hunt, U. S. Department of Agriculture, Forest Service, Forest Products Lab. R-919, 10 pp. 1933. (Mimeographed).

All infected parts should be replaced with naturally durable wood or with treated wood when repairs are being made to a building. It is advisable to remove all of the material for at least 2 feet beyond any evidence of decay because the funguous threads extend for quite a distance in advance of any visible decay.

50. Insects

The insects that inhabit logs and recently felled trees may continue their work in log structures, especially if the bark is left on the logs. The powderpost beetles are the only ones that may do serious damage after the logs have been cut into lumber and have been seasoned.

A. Beetles

Bark beetles may damage log structures and other rustic construction where the bark is left on the logs. They are reddish-brown to black insects, and vary in length from about one-sixteenth to one-fourth inch. They bore through the outer bark to the soft inner portion, and make tunnels of various types along which they lay their eggs. In making the tunnels, they push out fine brownish-white sawdust like particles which betray their presence under the bark. If many bettles are present, the extensive tunneling will loosen the bark and permit it ot fall off, making the structure unsightly.

Logs should be cut in October or November while bark beetles are in the larvae stage. If they are properly piled off the ground, in the open or under cover, to facilitate the rapid drying of the inner bark, the chance of damage by bark beetles is very slight. When the logs cannot be cut or handled as recommended, they should be immersed in a mixture containing 1 part of coal-tar creosote and 3 parts of kerosene to kill the beetle larvae.

Ambrosia beetles, round-headed borers and some powderpost beetles that get into freshly cut timber can cause considerable damage to the wood in rustic structures. If the timber is cut in October or November and properly seasoned, as just mentioned, the damage of ambrosia beetles can be controlled. Maximum protection may be obtained by the additional precaution of dipping the logs in the creosote-kerosene mixture in the Spring, before the first flight of the insects.

Powderpost beetles attack both freshly cut and seasoned hardwoods. The Lyctus species are especially active in the seasoned sapwood of a hardwood. The greatest damage is to ash, hickory and oak but the other hardwoods, including walnut, maple, persimmon, cherry, elm, poplar and sycamore, are also affected to some extent. Hardwood lumber and products that are left undisturbed in storage for long periods are especially susceptible to attack. The beetle eggs are laid in the pores of the wood. After hatching, the larvae burrow through the wood, making holes about one-sixteenth to one-twelfth inch in diameter, which they leave packed with a fine powder. Pow-

derpost damage is indicated by holes left in the surface of the wood as the larvae emerge, and also by the fine powder that falls from the wood during the emergence.

Evidences of powderpost infestation should not be overlooked when hardwood lumber is selected for building purposes, for the beetles may continue their activities after the lumber is in use. Beetle larvae are easily destroyed by sterilization with steam at not less than 130° F., or by heating in a dry kiln at 180° F. The time required is usually about $1\frac{1}{2}$ hours for inch lumber and proportionately more for thicker material. A thorough application of kerosene or a mixture of three parts kerosene and one part coal-tar creosote is effective where the use of these materials is practicable. A thorough swabbing with orthodichlorobenzene is recommended in case of powderposting of furniture or lumber installed in a building. Extreme care is necessary in the use of this chemical because of its caustic action. Painted or varnished surfaces are immune to infestation because the beetles lay their eggs in the open pores of the wood.

Stocks of susceptible hardwoods should not be allowed to remain undisturbed in manufacturing plants or warehouses for long periods but should be kept moving. Piling strips or stickers should be of heartwood or of some species that is not subject to Lyctus beetle attack, if they are to be re-used repeatedly. The premises should be kept clean of all waste wood and debris. Frequent inspections should be made, and all infested pieces of lumber should be treated by one of the methods mentioned above. Beetle attacks may be prevented by treating wood with boiled linseed oil, hardened gloss oil, or any other material that will plug up the pores and leave a substantial coating over the surface.

B. Termites*

Termites are frequently called "white ants" because they resemble ants in size and general appearance and have the same habit of living in colonies. About 56 species of termites are known in the United States. From the standpoint of their methods of attack on wood, the termites of the United States can be grouped into two main classes:

(1) The ground-inhabiting or subterranean termites which are found in nearly every State and are responsible for most of the termite damage to wood structures.

(2) The dry-wood termites which are found only in a narrow strip of territory extending from central California around the southern edge of the United States to Virginia.

*See Bureau of Entomology's Specification for the "Prevention of Termite Attack", U. S. Department of Commerce, Recommended Minimum Requirements for Small Dwelling Construction.

The subterranean termites develop their colonies and maintain their headquarters in the ground. They build their tunnels through earth and around obstructions to get at the wood they need for food. Each colony shuts itself off and lives in the dark. These termites will die unless they have a constant source from which to obtain moisture. The appearance of "flying ants" is an indication that a termite colony is near and perhaps causing serious damage. Subterranean termites do not establish themselves in buildings by being carried in in lumber but by entering from ground nests after the building has been constructed. If unmolested, they eat out the woodwork, leaving a shell of sound wood to conceal their activities. The damage may proceed so far as to cause collapse of portions of the structure before they are discovered.

The dry-wood termites are fewer in number, do not multiply so rapidly, and have a colony life and habits somewhat different from those of the subterranean termites. The total amount of destruction they cause in the United States is very much less than that caused by the subterranean termites. Their ability to live in dry wood without outside moisture or contact with the ground makes them a definite menace in the regions where they occur. Their depredations are not rapid, but they can thoroughly riddle timbers with their tunnelings if they are allowed to work unmolested for a few years.

Only a limited number of woods grown in the United States offer any marked degree of resistance to termite attack. California redwood and southern cypress have some resistance if used above the ground. Very resinous heartwood from southern pine is practically immune, but is not available in large quantities and is not suitable for many uses.

Where subterranean termites are prevalent, the best protection is to build to prevent their gaining access to the building. The foundations should be of concrete or other solid material through which the termites cannot penetrate. Cement mortar should be used with brick, stone or concrete blocks, because termites can work through some other kinds of mortar. Wood that is not impregnated with an effective preservative must be kept well away from the ground. Basements should be floored with concrete. Posts that support the first floor beams must not rest directly on the ground or on wood blocking unless it is thoroughly treated. They should rest on concrete piers extending a few inches above the basement floor, if that floor is of concrete. If the basement floor is of earth, the concrete piers should extend at least 18 inches above it. If the earth is not excavated beneath the building, the floor beams and other woodwork, unless adequately treated with preservatives, should be kept at least 2 feet from the ground. Good ventilation should be provided beneath the floor. All concrete forms, stumps, wood waste and the like should be removed from the building site. Stakes left embedded in concrete or beside concrete foundations afford easy means for termites to enter buildings and should be removed. Precautions that are effective against subterranean termites are also helpful against decay.

Termite shields should be placed between the foundation and the woodwork. These shields are sheets of metal that extend out from the foundation at an angle of 45° for a distance of at least two inches. They prevent the termites from extending their tunnels over the foundation to reach the sills. Metal shields should also be fitted tightly around water and sewer pipes, electrical conduits, or any similar equipment along which termites could gain entrance to woodwork.

If a building is to be constructed in localities where dry-wood termites are prevalent, the lumber should be carefully inspected to see that it has not become infested before arrival at the building site. If the building is constructed during the swarming season, the lumber should be watched during the course of construction, to prevent infestation by colonizing pairs.

All exposed wood should be well protected by paint to prevent the entrance of termites. Fine screen should be placed over any openings through which the termites might gain entrance to the interior, unpainted parts of the building. As in the case of ground-nesting termites, old stumps, posts, or wood debris should be removed from the premises.

If the wood in a building is found to be infested with dry-wood termites, it should be replaced. If it is difficult to replace, further activity may be arrested by blowing poisonous dust, such as finely divided paris green, arsenical dust, or sodium fluosilicate, into each nest.

C. Carpenter Ants

Carpenter ants are black or brown ants that infest decaying wood. They use the wood for shelter and not for food, but their tunnels soon weaken a structure. Precautions that prevent attack by decay and termites are usually effective against ants. Infested wood should be removed from the premises.

D. Marine Borers

Marine borers are mollusks or crustaceans that infest wood that is placed in salt water. The borers that do the most damage are shipworms, limnoria, martesia and sphaeroma. The shipworms and the martesia make small entrance holes and then increase in size after they are inside the wood. The limnoria and the sphaeroma do do most of their damage by burrowing along the outside edge of the piling.

51. Protection against Marine Borers

No wood is immune to the marine borer attack and no commercially important wood of the United States has sufficient resistance to justify its use, untreated, in any important permanent structure where borers are active.

Piling must be given a heavy treatment of coal-tar creosote if it is to be used in sea water. The treatments must be thorough, the penetration as deep as possible, and the absorption high to give satisfactory results. The piling should be treated "to refusal" by the full-cell process. The object is to force in all of the oil that the piling can be made to hold without causing serious damage to the wood. For highest absorptions, it is necessary to air-season the piling before it is treated. A thorough creosote treatment will not stop some marine borers. The average life of well-creosoted structures is many times that of untreated structures.

No cutting or framing should be allowed after the piles are treated. This is especially true for that portion of the pile which is to be under water. If the tops of piles are cut to grade above the water line, the exposed surfaces should be well protected to prevent decay.

If the importance of the structure and the difficulty or expense of renewing the piling are great enough to justify additional expense for insurance against attack in heavily-infested waters, the treated piling may be surrounded by a jacket of concrete, or by clay, tile, concrete or cast-iron pipe sections. The iron pipe would be the least liable to damage by breakage, but would be the most expensive. The pipe sections should extend from above high tide to a sufficient depth below the mud line to avoid the possibility of exposing the wood by scour. The space between the wood and the pipe should be filled with concrete.

Paint and batten methods of pile protection vary as to details, but consist substantially in:

(1) Coating the untreated pile with a thick, viscous paint which may or may not contain poisonous materials.

(2) Placing burlap, roofing felt or similar material over the paint.

(3) Applying a second of paint.

(4) Nailing a close-fitting layer of narrow battens over the paint.

(5) Applying a final coat of paint to fill the crevices between the battens, and to coat the surface thoroughly.

Experience has shown that only a moderate extension of life is to be expected from such treatment. With care in treatment, handling, and driving, it has been estimated that a life of 5 to 8 years may be expected from Douglas fir piling given such treatment and used in San Francisco Bay, but this may be greatly reduced by lack of care. In warmer waters the life span would be less. There would also be the danger of earlier destruction by decay of the untreated upper parts of the piles.

Surface coatings of preservatives or paints can give very little increase in life in borer infested waters. Damage from storms the rubbing of boats, or other causes breaks through the paint coating and allows the borers to work unhindered.

52. Piling of Untreated Lumber

Careful consideration should be given to the piling of untreated lumber in storage yards and at building sites. The following suggestions should be followed to preserve the lumber against the attacks of insects or fungus and deterioration by weathering.

A. When green or partially seasoned lumber is received at a storage yard, it should be piled on stickers, and covered with a rainproof roof. All of the stickers should be of the same thickness and should be spaced about 4 feet apart. Each pile of lumber should rest on three timbers, which, if placed directly on the ground, should be pressure treated with creosote.

B. When seasoned lumber is received at a storage yard, it should be solid piled in a shed that will give ample protection against wind and rain.

C. It is desirable to keep lumber piles off of the ground to prevent termite attack. If stickers are used, they should be of heart cypress, or some other equally durable species, or of treated material.

D. Flooring or interior trim should be stored in a heated storage place during damp weather in order to maintain the lumber at the desired moisture content. It should be stored as stated in paragraph "B" while awaiting use at a building site.

E. Dry lumber may be piled solidly in the open with the top and ends covered with a tough, moisture-retardent building paper while awaiting use at a building site. Stickers should be used to separate the successive layers of one-inch material. The use of stickers is not important with thicker stock.

F. Form lumber that is to be re-used should be cleaned and open piled with stickers and with a moisture-retardent cover so it will be protected from rain and sunshine. This care will permit form lumber to dry straight and free from most checks.

G. It is not necessary to be particular about piling lumber which is delivered at a building site in good weather and is to be used within two weeks or less. Short rains do not particularly harm the lumber, but it must be carefully piled and stored in continued wet weather.

Reference:

The material above quotes largely from the Wood Handbook, prepared by the Forest Products Laboratory, Forest Research, Forest Service.

CHAPTER VIII - SELECTION AND USE OF WOOD PRODUCTS

53. Forest Service Policy Relative to the Use of Wood

The following policy covering the use of wood in Forest Service structures has been approved and should be followed in deciding on materials to be used:

> "A function of the Forest Service is to foster not only the production but also the use of wood. From a utilization standpoint our aims go beyond the reduction of waste and the increase in usefulness and value of wood products. We aim to insure the permanent place of wood in our modern economy, and thus give incentive and reality to a nation-wide program of forestry by which lands otherwise idle can be made a source of wealth and employment.
>
> "The Forest Service in its own construction work should use wood to the fullest practicable degree. The use of other materials in lieu of wood should be considered and authorized only when their suitability and durability clearly exceed that of wood, or where the use of such substitute materials is made necessary by the general type or design of the structure, or where the first cost plus maintenance cost of wood would so greatly exceed the first cost plus maintenance of other materials that it cannot be justified on any demonstrational or economical basis, or where the use of lumber is at variance with City, County, and State building codes."

54. Lumber - Definitions

A. Native Lumber

Native lumber includes all lumber of local manufacture as it comes from the saw as boards, dimension, or timbers. Also included under this head are all local growing species, either in round logs, sections of logs, or sawed or dressed timber which is manufactured and sold but which is not graded for selling on the basis of standard grading rules promulgated by the Forest Products Laboratory or the National Lumber Manufacturers' Association, or its recognized members.

The use of Native Lumber will usually be restricted to temporary construction and cases where the material is particularly adapted to the purpose at hand. Generally, because of the low standard of manufacture and limited selection possibilities, its use

demands considerable skill and work to put in place. Many fine decorative and substantial uses can be obtained if native materials are properly handled.

B. Manufactured Dimension Lumber

Manufactured Dimension Lumber may be said to include all lumber manufactured to meet the standard grading rules of the following principal recognized lumber manufacturers' associations.

Principal Lumber Manufacturers' Associations and Woods Graded Under the Rules of Each Association

Name and Address	Woods Covered by Grading Rules
Hardwood Dimension Mfgrs. Assn. Memphis, Tenn.	Hardwoods (dimension or cut stock)
Hardwood Interior Trim Mfgrs. Assn. 63 S. 3rd. St., Memphis, Tenn.	Hardwood (trim)
Hardwood Mfgrs. Institute, Memphis, Tenn.	No grading rules
Maple Flooring Mfgrs. Assn. 332 S. Mich. Ave., Chicago	Maple (northern hard) (F.S. name, hard maple), beech, birch (flooring)
Nat'l Hardwood Lumber Assn. 2408 Buckingham Bldg., Chicago	Hardwoods, cypress, (F.S. name, southern cypress) aromatic red cedar
Nat'l Oak Flooring Mfgrs. Assn. 604 Dermon Bldg., Memphis Tenn.	Oak (flooring)
Calif. Redwood Assn., 405 Montgomery St., San Francisco, Calif.	Redwood
Northeastern Lumber Mfgrs. Assn. Chanin Bldg., New York City.	Balsam fir, northern white pine, eastern hemlock & eastern spruce
Northern Hemlock & Hardwood Mfgrs. Assn., Oshkosh, Wisc.	Eastern Hemlock, tamarack, northern white cedar
Northern Pine Mfgrs. Assn., Lumber Exchange Bldg., Minneapolis.	Northern white pine, Norway pine, eastern spruce, and jack pine
Southern Cypress Mfgrs. Assn., Barnett Nat'l Bank Bldg., Jacksonville, Fla.	Southern cypress (upland & tidewater types) (F.S. name, southern cypress)

Name and Address	Woods Covered by Grading Rules
Southern Pine Assn., New Orleans, La.	Longleaf and shortleaf southern yellow pine
West Coast Lumbermen's Assn., Stuart Bldg., Seattle, Wash.	Douglas fir (coast region) west coast hemlock (F.S. name, western hemlock), Sitka spruce, western red cedar, Port Orford cedar
Western Pine Assn., Yeon Bldg., Portland, Oregon	Ponderosa pine, Idaho white pine, (F.S. name, western white pine), sugar pine, western larch, Douglas fir, ("Inland Empire" & California), white fir, Engelmann spruce, incense cedar and western red cedar
Red Cedar Shingle Bureau, Stuart Bldg., Seattle, Wash.	Western red cedar (shingles)

55. Considerations in Grading Lumber

When a large tree is sawed, it yields boards of widely varying quality. Lumber grades divide the product of the tree into several segregations, each having a relatively narrow range in quality. This division enables the user to buy the quality that best suits his use and purpose.

Except as noted later, the grade of a piece of lumber is based on the number, character and location of features commonly referred to as defects and defined as "any irregularity occurring in or on wood that may lower some of its strength, desirability, or utility values." Among the more common of such features are knots, checks, pitch pockets, shakes, and stains, some of which are a natural part of trees. The best grades are practically free from these features, while the other grades, comprising the great bulk of lumber, contain knots and other natural growth characteristics. These characteristics do not prevent such lumber from giving satisfaction for a great variety of uses.

Those associated with the use of lumber should have copies of the grading rules that are in effect in the territory in which their work is located. They should be able to check properly all lumber material received, to make sure that it meets the specifications under which it was purchased.

56. Finish or Select Lumber - Grade Qualities and Uses

Select grades provide for good appearance and finishing qualities. Grades A and B are suitable for natural finishes, and grades C and D are suitable for paint finishes. A grade of clear heartwood is available in a few species where there is a pronounced difference in color between heartwood and sapwood and where a high

natural resistance to decay is required.

Grade A is practically clear wood. It is manufactured for such items as finish, flooring, ceiling, partition, and siding. A large number of manufacturers do not segregate the grade even in these items, and some of the lumber associations do not recognize the quality as a separate grade. Where the grade is not segregated, it is combined with grade B and sold as B and Better. Grade A lumber is used almost entirely for interior and exterior trim and for flooring. The demand is small and is confined largely to high class construction, such as office buildings and expensive residences.

Grade B allows a few small imperfections. In practice, these small imperfections mainly take the form of minor skips in manufacture and small checks or stains due to seasoning, and depending on the species, small pitch areas, pin knots, etc. are classed as small imperfections. Grade A pieces in the mixed grade are practically clear, but the average board contains 1 or 2 small imperfections. Grade B and Better is the grade most commonly used for high-class interior and exterior trim, especially where these are to receive a natural finish. It is the principal grade used for flooring in homes, offices and public buildings. In industrial uses Grade B finish meets the special requirements for large-sized, practically clear stock.

Grade C allows a limited number of small imperfections that can be easily covered with paint. Specifically, the number of these, per board, averages about twice that allowed for B and Better. The proportion of small knots in Grade C is greater than in B and Better. Grade C lumber is especially adapted to use where a high-class paint finish is desired. It is excellent material for cornices, porch flooring, porch columns, bedroom and kitchen trim, built-in kitchen fixtures and siding. It is used to some extent for natural finishes in medium and low priced dwellings and offices.

Grade D allows any number of surface imperfections that do not detract from the appearance of the finish when painted. In practice, the number of such surface features per board averages three to five times as many as in B and Better. Certain natural and manufacturing imperfections are not much more numerous in Grade D than in Grade C, but the number and size of the knots is considerably greater. The back of Grade D lumber is usually of somewhat lower quality. Commercial grading permits an occasional coarse knot or hole in Grade D that may be cut out with restrictions as to waste. Grade D is in reality a one-face grade - that is, only one face shows in actual use. It has the same construction uses as Grade C. It goes into moderate or low-priced houses, furnishing a medium-priced lumber for casing, cornice work, shelving and built-in fixtures that are to be painted. It is also used extensively for millwork and molding, and is adaptable to industrial uses reuqiring short length clear lumber.

The knots occurring in Grade B and Better are predominantly under one-half inch in diameter and have smooth, hard surfaces. A

small proportion of the knots in Grade C are as large as 1 inch in diameter, and a few are not of the best quality. A few knots in Grade D lumber are more than 1 inch in diameter and are slightly soft, rough or loose.

Depending on the species, the highest commercially recognized grade may be C and Better or D and Better, but no such combination of grades, except B and Better, is recognized in American lumber standards unless the actual proportions in the mixed grade are specified in the invoice.

Seasoning faults, such as check, either in flat surfaces or at the ends of boards, are among the more frequent imperfections in the select grades. Imperfect seasoning often causes a lowering of grade, but the number of such occurrences is considerably reduced at plants of careful manufacturers.

Pitch pocket is a relatively common imperfection in the select grades of several species, but occurs less frequently than knots in all except one of the important species. The variation among grades in the number and size of pitch pockets is not so marked as in the case of knots. The frequency of pitch pockets as compared with other forms of pitch varies considerably among the species.

Other features that are factors in the select grades are stain, and chipped and torn grain.

57. Boards - Grade Qualities and Uses

The term "boards" includes lumber less than 2" thick which is not suitable for classification as finish or select. Boards are available at all yards in one or more of the kinds of wood most frequently used in building. They are usually of nominal 1-inch thickness dressed two sides to twenty-five thirty-seconds of an inch. Thinner stock is sometimes offered, but it should not be classed as standard lumber. The standard nominal widths are 6, 8, or 10 inches or sometimes wider.

Grades of boards contain features that detract from the appearance of the finish but are suitable for general utility and construction purposes. The differences between the various board grades are due to the character more than to the number of such features as knots, pitch, and the like. The number of knots in a board averages, in different species, about 5 to 20 per 8 board feet, regardless of grade. No. 1 and No. 2 boards are for use without waste. No. 3, No. 4 and No. 5 boards permit a limited amount of waste.

No. 1 boards are described in the basic classification as sound and tight-knotted stock in which the size of the knot is limited. The provisions further state that it may be considered as watertight lumber. In most species, practically all boards in the grade contain knots, although in some species pitch is the predominant characteristic of the grade. The size of the knots varies with

the species. From one-half to three-fourths of the knots are usually intergrown. The remaining knots are incased, and a small proportion are unsound, broken or checked.

No. 1 boards are used in construction for both finish and covering. As a finishing lumber this grade is used for siding, cornices and other exterior trim in medium and low priced homes, and for sheathing and roof boards in the more expensive type of buildings. It is well adapted to coverage for farm buildings, expecially where a weathertight structure is required. Its use for interior trim is confined to cheaper construction and where high-class paint finishes are not required. In this grade it is difficult to entirely conceal the knots with paint. The No. 1 board is a general-utility item in industrial use. It is used extensively for door and window frames and for backing and concealed parts of furniture and fixtures.

No. 2 boards are classified as allowing large and coarse features such as knots that may be considered grain-tight. In practice, a small amount of thru-shake, thru-pitch pockets and decay is permitted in the grade. The proportion of large knots is greater than in No. 1, and while 33 to 75 percent of the knots are intergrown, 10 percent or more are usually unsound, loose or otherwise partially open. Some commercial grading rules allow knot holes in the grade, provided they are strictly limited as to size and number. No. 2 boards are used primarily as coverage where the wood is not painted or otherwise finished. Sub-floors, sheathing, and concrete forms are typical uses for the grade. Dressed and matched, it is used for rough flooring in inexpensive farm and factory buildings, garages, warehouses, and the cheaper types of cottages. It is extensively used for barn boards laid up vertically and for drop siding for barns, garages and warehouses. The popular type of knotty finish is largely selected from this grade. Industrially, No. 2 boards go into the same uses as No. 1 boards, but are better adapted to uses requiring short lengths or small pieces than to uses requiring the board as a whole.

No. 3 boards are classified as allowing larger and coarser knots than No. 2 boards and also occasional knot holes. A larger portion of large knots and an increased amount of shake, decay, and holes distinguish No. 3 boards from No. 2 boards. No. 3 boards are used in construction for concrete forms, sheathing, subfloors, roof boards and temporary construction. They fill a demand from builders of less exacting types of buildings for a cheaper material than No. 2. Industrially, they are extensively used for boxes and crates.

No. 4 and No. 5 boards are provided for in American lumber standards but are not produced in some species. No. 4 is described in the basic-grade classification as a low quality lumber admitting of the coarsest features, such as decay and holes. The only requirement as to the quality of No. 5 lumber is that it hold together under ordinary handling.

No. 4 boards are not graded for general use. They are used for sheathing, subfloors, and roof boards in the cheaper types of construction. The use of the grade for these purposes involves some additional labor and a small amount of waste in cutting out defective material. Boxes and crates are the most important industrial outlet for the grade.

No. 5 boards are seldom shipped far from the mill and are not commonly available at retail yards in non-forested regions. They are used for rough and temporary coverage of buildings and for boxes and crates.

In cases where commercial grading rules divide the entire range of boards into three grades instead of 5 grades as in American lumber standards, the first or highest grade of the 3-grade division will normally contain material with a wider range in quality than the first grade of the 5-grade division. The third or lowest grade of the 3-grade division will contain lower quality material than the third grade of the 5-grade division. This fact, and the difference in inherent properties of different species makes it impossible to consider the common grades of corresponding name for the different woods as interchangeable in use.

In most species one-third to two-thirds of the knots in the grades of boards are intergrown, while in the select grades of finish items, intergrown knots comprise only a small proportion of the total. Intergrown knots may check if large, but they do not loosen or drop out because they are integral parts of the wood.

In some species a large number of the incased knots remain tight, but in other species many of them become loose. The loosening becomes more pronounced in large knots and as the lumber becomes drier. As a rule, incased knots comprise a larger percentage of the total number of knots in the small-knotted select grades than they do in the larger-knotted grades of boards.

Spike knots are formed by cutting a branch lengthwise rather than crosswise. They occur infrequently in grades better than No. 2 boards.

Wood that contains small areas of clearly evident decay is not permitted in grades better than No. 2 boards.

58. Dimension or Framing Lumber - Grade Qualities and Uses

Dimension is primarily framing lumber, such as joists, rafters, studding and planking for heavy floors. Its essential requirements are strength, stiffness and uniformity of size. It is stocked in all yards, but usually in only one of the general-purpose construction woods, such as pine, fir, hemlock or spruce. Dimension is lumber 2 to 5 inches in thickness and of any width. The nominal thickness is usually 2 inches dressed 1 or 2 sides to 1-5/8". The nominal width is 4, 6, 8, 10 or 12 inches and the length is from 4 to 18 feet, in multiples of 2 feet.

Dimension is graded primarily on its strength, stiffness and straightness. Grading is based principally on the requirements for framing for buildings. The dimension grades are best adapted to use where stiffness is the controlling factor as in joists and studs, or where the size of the member is determined by common building practice instead of being specially designed to carry definite live and dead loads. Rafters of dwelling houses are good examples of members whose size is generally determined by common practice rather than by special design.

No. 1 dimension is a sound grade allowing knots limited in size, depending upon the size of the piece. Features, such as pitch, torn grain, checks and stain, that do not materially affect the strength of the piece are not limited. Wane is limited to provide good nailing on one side and two edges.

The grade is used for joists, rafters, scaffolding, light framing and for less exacting items in heavier framing. It is also used for planking for warehouses, platforms and other heavy-duty flooring where the wearing surface rather than load-carrying capacity is the important factor. The structural grades of joists and plank should be used in preference to dimension grades for flooring designed to carry heavy loads.

No. 2 dimension admits large, coarse, unsound knots, warped pieces, certain types of decay, fair nailing edges and other features that will not weaken the piece to an extent that will render it unfit for use as a whole.

It is used in construction for joists and rafters in medium priced, light frame construction and for plates, sills, studding, and other vertical load bearing members in high-priced light construction. It is used as a flooring to provide wearing surface where the load is not carried by the wood floor. It is used industrial for crating and for other work where short lengths are required.

No. 3 dimension includes all pieces which fall below the No. 2 grade and are suitable for use in cheap building. It admits all features of No. 2 without limitations on size or number, providing they do not seriously affect the utility of the piece or involve waste of more than 25 percent in one-third of the pieces. It is used for studding in low-priced and temporary light frame construction. No. 3 dimension may be cut and used with considerable economy in small buildings where the members are short.

59. Structural Material - Grade Qualities and Uses

Structural material is divided into three classes, as follows:

A. Joist and Plank - Pieces of rectangular cross-section graded with respect to their strength in bending when loaded on the narrow face as a joist or on the wide face as a plank. The nominal sizes are from 2 to 4 inches in thickness and 4 inches or more in width.

B. Beams and Stringers - Large pieces of rectangular cross-section graded with respect to their strength in bending when loaded on the narrow face. The nominal sizes are 5 by 8 inches and larger.

C. Posts and Timbers - Pieces of square cross-section grade for use as posts or columns, but adapted to miscellaneous uses in which strength in bending is not especially important. The nominal sizes are 4 by 4 inches and larger.

The three tables on Pages 80, 81 and 82, from A.S.T.M. specifications summarize standard sizes, stress-grades and working stresses for joist and plank, beams and stringers, and posts and timbers. They offer a valuable key to different structural grades.

Structural material is graded on a basis of strength and is intended for use where working stresses are required. A full discussion of structural grades and appropriate working stresses will be found on Pages 99 to 117 inclusive, in the "Wood Handbook", prepared by the Forest Products Laboratory.

60. Standard Lumber Patterns

Six typical lumber patterns are illustrated below:

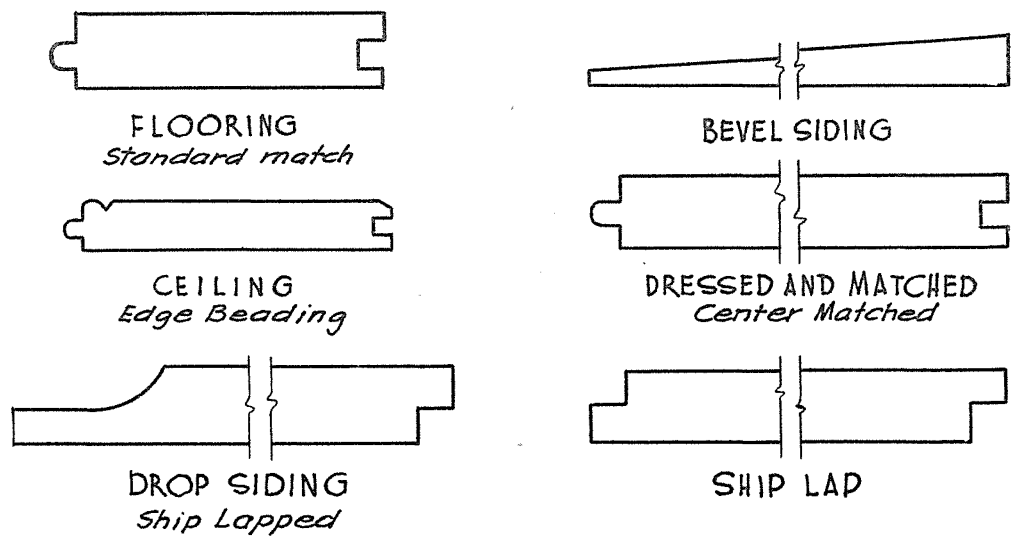


TABLE A - STANDARD SIZES, STRESS-GRADES, AND WORKING STRESSES FOR STRUCTURAL JOIST AND PLANK

Standard Sizes

Nominal thicknesses ..... 2, 3 and 4 in.
Permissible minimum rough thicknesses in not to exceed 20 per cent of pieces in any one shipment:
- 2 in. ..... 1/8 in. off
- 3 and 4 in. ..... 3/16 in. off

Dressed thicknesses, S1S or S2S ..... 3/8 in. off
Nominal widths ..... 4 in. and wider
Permissible minimum rough widths in not to exceed 20 per cent of pieces in any one shipment:
- 4 and 6 in. ..... 3/16 in. off
- 8 in. and wider ..... 1/4 in. off

Dressed widths, S1E or S2E:.....
- 4 and 6 in. ..... 3/8 in. off
- 8 in. and wider ..... 1/2 in. off

Standard Stress-Grades and Working Stresses

(Continuously Dry Locations)

Grades and Species	Fiber Stress Bending Tension lb. sq. in.	Max. Horiz. Shear lb.	Comp. Perp. to Grain lb.	Mod. of Elast. lb. sq. in.
1800 lb. f Dense Douglas Fir (Coast and Inland).....	1800	120	380	1 600 000
1800 lb. f Dense Longleaf or Dense Shortleaf Southern Pine.....	1800	120	380	1 600 000
1600 lb. f Close-Grained Douglas Fir (Coast)	1600	100	345	1 600 000
1600 lb. f Dense Longleaf or Dense Shortleaf Southern Pine	1600	120	380	1 600 000
1600 lb. f Close-Grained Redwood	1600	80	267	1 200 000
1400 lb. f Tidewater Red Cypress	1400	120	300	1 200 000
1400 lb. f Oak	1400	120	500	1 500 000
1400 lb. f Dense Longleaf Southern Pine	1400	100	380	1 600 000
1400 lb. f Close-Grained Redwood	1400	80	267	1 200 000
1200 lb. f Port Orford Cedar...	1200	100	250	1 200 000
1200 lb. f Douglas fir (Coast)	1200	100	380	1 600 000
1200 lb. f Dense Shortleaf Southern Pine	1200	100	380	1 600 000
1200 lb. f Close-Grained Redwood	1200	70	267	1 200 000
1100 lb. f Port Orford Cedar ..	1100	80	250	1 200 000
1100 lb. f Tidewater Red Cypress	1100	100	300	1 200 000
1100 lb. f Oak	1100	100	500	1 500 000
1000 lb. f Western Red Cedar...	1000	100	200	1 000 000

TABLE B - STANDARD SIZES, STRESS-GRADES, AND WORKING STRESSES FOR STRUCTURAL BEAMS AND STRINGERS

Standard Sizes

Nominal thicknesses	5 in. and thicker
Permissible minimum rough thicknesses in not to exceed 20 per cent of pieces in any one shipment:	
5 and 6 in.	3/16 in. off
8 in. and wider	1/4 in. off
Dressed thickness, S1S or S2S	1/2 in. off
Nominal widths	8 in. and wider
Permissible minimum rough widths in not to exceed 20 per cent of pieces in any one shipment	1/4 in. off
Dressed widths, S1E or S2E	1/2 in. off

Standard Stress-Grades and Working Stresses

(Continuously Dry Locations)

Grades and Species	Fiber Stress Bending Tension lb. sq. in.	Max. Horiz. Shear lb.	Comp. Perp. to Grain lb.	Mod. of Elast. lb. sq. in.
1800 lb. f Dense Douglas Fir (Coast and Inland)	1800	120	380	1 600 000
1800 lb. f Dense Longleaf or Dense Shortleaf Southern Pine	1800	120	380	1 600 000
1600 lb. f Close-Grained Douglas Fir (Coast)	1600	100	345	1 600 000
1600 lb. f Dense Longleaf or Dense Shortleaf Southern Pine	1600	120	380	1 600 000
1600 lb. f Close-Grained Redwood	1600	80	267	1 200 000
1400 lb. f Tidewater Red Cypress	1400	120	300	1 200 000
1400 lb. f Oak	1400	120	500	1 500 000
1400 lb. f Dense Longleaf Southern Pine	1400	100	380	1 600 000
1400 lb. f Close-Grained Redwood	1400	80	267	1 200b000
1200 lb. f Dense Shortleaf Southern Pine	1200	100	380	1 600 000
1200 lb. f Close-Grained Redwood	1200	70	267	1 200 000
1100 lb. f Port Orford Cedar.	1100	80	250	1 200 000
1100 lb. f Tidewater Red Cypress	1100	100	300	1 200 000
1100 lb. f Oak	1100	100	500	1 500 000
1000 lb. f Western Red Cedar.	1000	100	200	1 000 000

TABLE C - STANDARD SIZES, STRESS-GRADES, AND WORKING STRESSES FOR STRUCTURAL POSTS AND TIMBERS

Standard Sizes

Nominal thicknesses	5 in. and thicker
Permissible minimum rough thicknesses in not to exceed 20 per cent of pieces in any one shipment:	
5 and 6 in.	3/16 in. off
8 in. and wider	1/4 in. off
Dressed thicknesses, S1S or S2S	1/2 in. off
Nominal widths	5 in. and wider
Permissible minimum rough widths in not to exceed 20 per cent of pieces in any one shipment:	
5 and 6 in.	3/16 in. off
8 in. and wider	1/4 in. off
Dressed widths, S1E or S2E	1/2 in. off

Standard Stress-Grades and Working Stresses

(Continuously Dry Locations)

Grades and Species	Comp. Parallel to Grain, Short Columns, Lb. Per Sq. In.	
1300 lb. c Dense Douglas Fir (Coast and Inland)	1300	
1300 lb. c Dense Longleaf or Dense Shortleaf Southern Pine	1300	
1200 lb. c Tidewater Red Cypress	1200	
1200 lb. c Close-Grained Douglas Fir (Coast)	1200	For stresses in compression perpendicular to grain and modulus of elasticity see values in Table B for Beams and Stringers
1200 lb. c Dense Longleaf or Dense Shortleaf Southern Pine	1200	
1200 lb. c Close-Grained Redwood	1200	
1100 lb. c Douglas Fir (Coast)	1100	
1100 lb. c Oak	1100	
1100 lb. c Close-Grained Redwood	1100	
1000 lb. c Port Orford Cedar	1000	
1000 lb. c Tidewater Red Cypress	1000	
1000 lb. c Oak	1000	
1000 lb. c Dense Longleaf Southern Pine	1000	
1000 lb. c Close-Grained Redwood	1000	
900 lb. c Port Orford Cedar	900	
900 lb. c Dense Shortleaf Southern Pine	900	
800 lb. c Western Red Cedar	800	

The detailed reasoning basic to these grades will be found by a study of a report of the U. S. Forest Products Laboratory, U. S. Department of Agriculture "Miscellaneous Publication No. 185" entitled "Guide to the Grading of Structural Timbers and the Determination of Working Stresses," February, 1934. Reference should also be made to the "Working Stresses," appearing in the Appendix to the Standard Specifications for Structural Wood Joist and Plank, Beams and Stringers, and Posts and Timbers (ASTM Designation D 245-36T) of the American Society for Testing Materials.

1931 7000 Series	Finished Size Inches	1931 7000 Series	Finished Size Inches
7001	3/4 x 1-5/8	7050	1-1/16 x 1-5/8
7002	3/4 x 2-1/8	7055	3/4 x 1-5/8
7003	3/4 x 2-5/8	7057	5/8 x 1-5/16
7004	3/4 x 3-1/8	7060	1-1/16 x 2
7005	3/4 x 3-1/8	7061	1-1/16 x 2
7006	3/4 x 4	7062	1-5/8 x 2
7007	3/4 x 4-1/2	7063	1-5/8 x 2
7010	3/4 x 1-5/8	7070	3/4 x 3/4
7011	3/4 x 2-1/8	7072	1-1/16 x 1-1/16
7012	3/4 x 2-5/8	7073	1/2 x 3/4
7013	3/4 x 3-1/8	7083	1/2 x 1/2
7014	3/4 x 3-1/2	7084	5/8 x 5/8
7015	3/4 x 4	7085	3/4 x 3/4
7016	3/4 x 4-1/2	7087	3/4 x 1-3/8
7022	3/4 x 1-5/16	7088	3/4 x 1-5/8
7023	3/4 x 1-5/8	7091	1/4 x 7/16
7024	3/4 x 1-7/8	7092	5/16 x 5/8
7025	3/4 x 2-1/8	7093	3/8 x 11/16
7026	3/4 x 2-5/8	7094	1/2 x 1
7027	3/4 x 3-1/8	7096	3/4 x 1-1/2
7029	3/4 x 2-5/8	7101	1/4 x 3/4
7030	1/2 x 3/4	7102	1/4 x 3/4
7031	5/8 x 7/8	7103	5/16 x 5/8
7032	3/4 x 7/8	7104	3/8 x 3/4
7033	3/4 x 1-1/16	7105	5/8 x 1-3/8
7035	3/4 x 1-5/8	7106	9/32 x 5/8
7036	3/4 x 2-1/8	7107	9/32 x 1/2
7037	3/4 x 2-5/8	7108	3/8 x 1/2
7038	3/4 x 3-1/2	7109	9/32 x 1-3/8
7039	3/4 x 4-1/2	7110	9/32 x 1-3/8
7040	1-1/16 x 5-1/2	7111	9/32 x 1-3/8
7041	3/4 x 4-1/2	7116	3/4 x 1-5/8
7042	3/4 x 3/4	7117	3/4 x 2-1/8
7043	5/8 x 7/8	7118	3/8 x 1-5/16
7044	3/4 x 1-1/16	7119	5/8 x 2-1/8
7045	3/4 x 1-5/8	7130	1/2 x 1-1/16
7046	5/8 x 3/4	7131	1/2 x 1-5/16
7047	3/4 x 1-1/16	7132	3/8 x 1
7048	3/4 x 1-5/16	7133	3/4 x 1-5/8
7049	1-1/16 x 1-5/16	7134	9/16 x 2

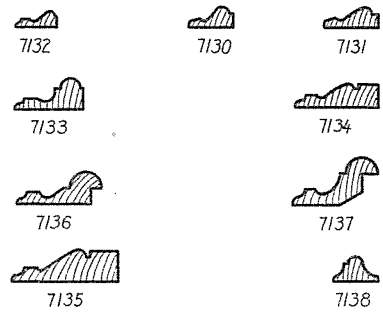
Where the "8000" Series are still used, they may be selected and specified by their comparable "8000" number.

List of Mouldings (Continued)

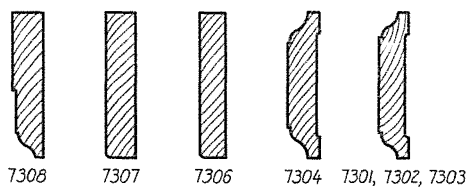
1931 7000 Series	Finished Size Inches	1931 7000 Series	Finished Size Inches
7135	3/4 x 2-1/2	7241	1/2 x 1-1/16
7136	3/4 x 2	7242	1/2 x 1-3/8
7137	3/4 x 2-1/8	7243	1/2 x 1-5/8
7138	5/8 x 1-1/16	7244	1/2 x 1-7/8
7140	3/4 x 1-5/8	7260	3/4 x 1-3/8
7141	5/8 x 1-5/8	7261	3/4 x 1-5/8
7142	5/8 x 1-5/8	7262	3/4 x 1-5/8
7145	3/4 x 2-5/8	7263	3/4 x 1-5/8
7146	3/4 x 2-5/8	7264	3/4 x 2-5/8
7149	3/4 x 15/16	7265	1-5/16 x 1-5/16
7150	3/4 x 1-1/16	7266	3/4 x 2-3/8
7151	1-1/16 x 1-1/16	7267	1-5/16 x 2-3/8
7152	1-1/16 x 1-1/16	7268	3/4 x 1-5/8
7153	1-1/16 x 1-5/16	7269	1-5/16 x 2
7154	1-1/16 x 1-5/16	7270	3/4 x 2
7156	3/4 x 11/16	7281	3/4 x 1-5/8
7161	1-1/16 x 1-5/8	7282	3/4 x 2-1/8
7162	1-1/16 x 2	7286	5/8 x 3-1/2
7163	1-5/16 x 2-1/8	7287	5/8 x 3-1/2
7171	1/4 x 1/2	7291	5/8 x 2-5/8
7172	3/8 x 7/16	7292	5/8 x 3-1/2
7173	3/8 x 5/8	7293	3/4 x 3-1/2
7174	3/8 x 1/2	7298	1-1/16 x 3-1/2
7175	1/2 x 9/16	7301	11/16 x 3-1/2
7176	1/2 x 3/4	7302	11/16 x 4-1/2
7181	5/16 x 1-1/16	7303	11/16 x 5-1/2
7182	5/16 x 2-1/8	7304	3/4 x 3-1/2
7185	3/8 x 1-1/16	7306	5/8 x 3-1/2
7186	7/16 x 1-1/16	7307	3/4 x 3-1/2
7221	3/8 x 3/4	7308	3/4 x 3-1/2
7222	3/8 x 1-1/16	7311	3/4 x 3-1/4
7223	3/8 x 1-3/8	7312	1-1/16 x 3-1/2
7224	3/8 x 1-5/8	7313	1-1/16 x 4-1/2
7225	1/2 x 1-1/16	7314	1-1/16 x 5-1/2
7226	1/2 x 1-3/8	7316	1-1/16 x 3-1/4
7227	1/2 x 1-5/8	7317	1-1/16 x 4-1/4
7228	1/2 x 1-7/8	7445	5/8 x 3-1/2
7229	1/2 x 2-5/8	7501	5/16 x 1-1/16
7236	1/2 x 1-3/8	7502	5/16 x 1-3/8
7237	1/2 x 1-5/8	7503	5/16 x 1-5/8
7238	1/2 x 1-7/8		

Where the "8000" Series are still used, they may be selected and specified by their comparable "8000" number.

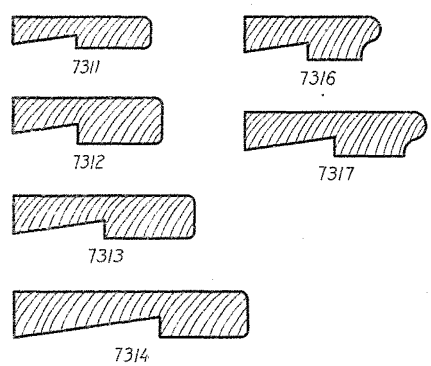
BATTENS



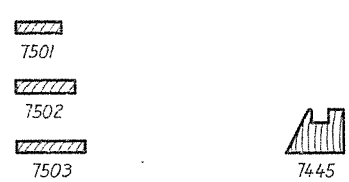
PANEL MOLDINGS



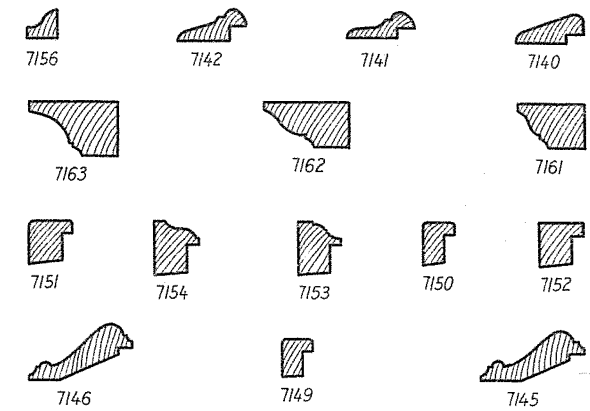
CHAIR RAILS, TRANSOM COVERS, MULLION CASTINGS AND APRONS



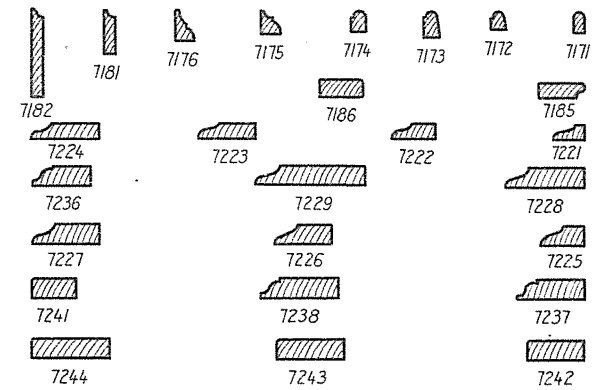
WINDOW STOOLS



LATTICE SHOE MOLDING



CAP AND BACKBAND MOLDINGS



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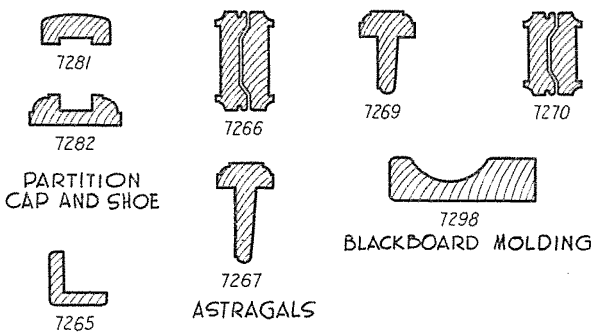
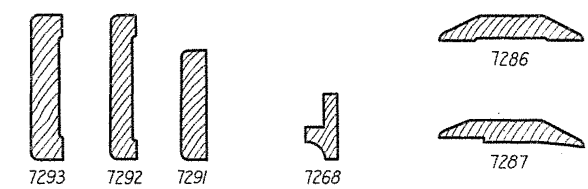


CORNER BEAD

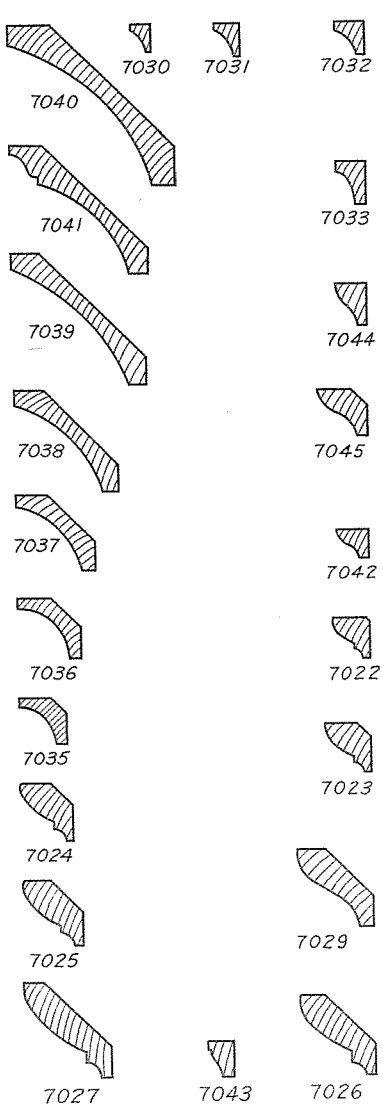


HOOK STRIP SHELF CLEAT THRESHOLDS

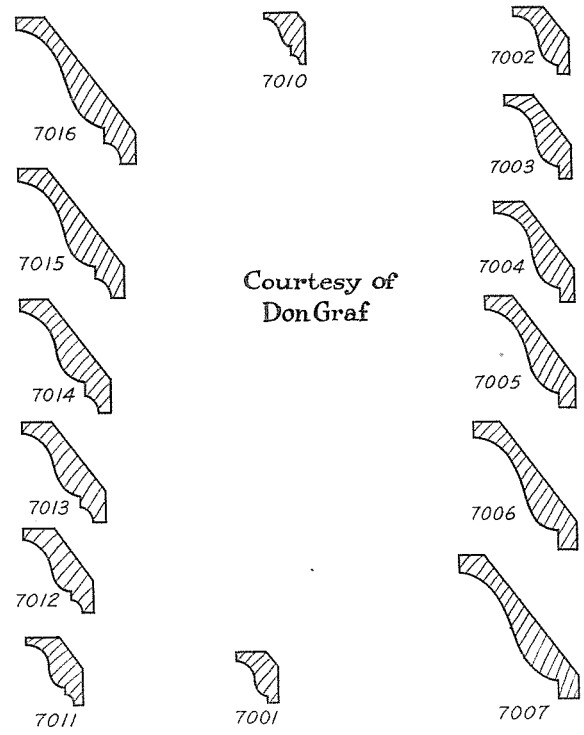
For finished sizes see numerical list.

Courtesy of Don Graf.

STANDARD WOOD MOULDINGS

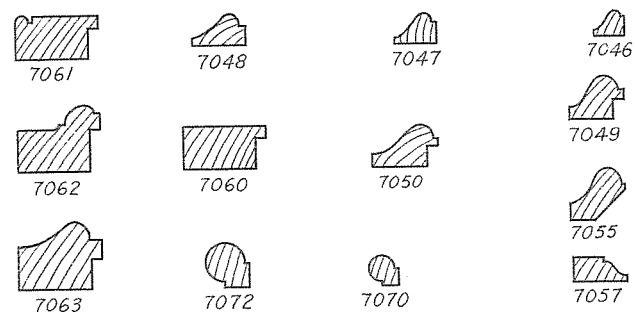


BED AND COVE MOLDINGS

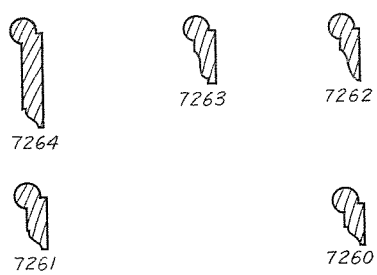


Courtesy of
Don Graf

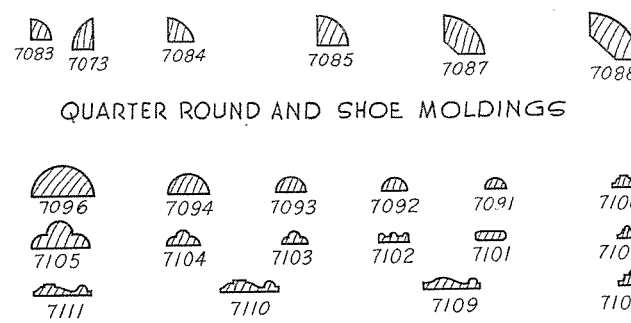
CROWN MOLDINGS



STAFF BEAD AND BRICK MOLDINGS



PICTURE MOLDING



QUARTER ROUND AND SHOE MOLDINGS

PANEL, HALF ROUND AND SCREEN MOLDINGS

For Finished sizes see numerical list.

STANDARD WOOD MOULDINGS

Softwood flooring is always made "standard match" which means that the upper lip of the groove is thicker than the lower. The lower lip is the same thickness for all standard flooring.

Ceiling, which is thinner than 1 inch, is usually machined with a bead and V. Partition, which is thicker than ceiling, usually has a bead and a V on both sides. Drop siding is usually made from one inch lumber and is made in more patterns than any other product except molding. Some of these patterns are shiplapped, while others are tongued and grooved. Bevel siding is made by re-sawing 4/4 inch or 5/4 inch lumber on an angle.

Square edged lumber in either boards, timber, or dimension, forms only rectangles of different dimensions. Boards are frequently dressed and matched (D&M), in which event the tongue and groove are in the center, making the pieces center matched. Molding lists are shown on Pages 83 and 84.

61. Lumber Items Usually Carried in Retail Yards

The small retail yards throughout the United States carry softwoods used for ordinary construction purposes. They sometimes carry small stocks of one or two hardwoods in the grades suitable for finish or cabinet work. Any particular hardwood may be obtained by special order through the retail lumber yard. Hardwoods are used chiefly for interior trim, cabinets, and flooring. In modern practice, trim items are cut to size in standard patterns at millwork plants and are sold in such form by the retail yards. Cabinets are usually made by the millwork plant ready for installation on the job by the carpenter. Hardwood flooring is invariably a planing-mill product and is available to the buyer only in standard patterns.

The assortment of general construction items carried by retail yards depends upon geographical location. For instance, in the Pacific Northwest, local yards will stock Douglas fir, spruce, ponderosa pine, western hemlock and western red cedar. An Iowa yard will stock eastern hemlock, northern white pine, ponderosa pine, southern yellow pine and Doublas fir. A New York yard might stock eastern spruce and hemlock, northern white pine, cypress, ponderosa pine, southern yellow pine and Douglas fir. Lumber from the Pacific coast is readily available in the eastern part of the United States because of low-cost water transportation via the Panama Canal. For some species, only certain items may be available. Southern yellow pine or Douglas fir may be stocked only in the form of dimension or piece items. Eastern hemlock may be stocked only in sheathing and inch boards. Cypress and redwood may be stocked only in finish boards and plank or in siding.

Wholesalers do not ordinarily stock lumber. However, some large wholesalers located in extensive lumber-consuming districts have yards wherein are stocked many kinds of lumber, both hardwood and softwood. These wholesalers supply the varied needs of retail yards, wood-using factories, and large contractors.

62. Flooring

Flooring is made chiefly of the harder softwoods such as Douglas fir, western larch and southern pine and of hardwoods such as maple and oak. The nominal widths are usually 3 and 4 inches. Thicker flooring is available in hardwoods and softwoods for heavy duty floors. Thinner material is available in hardwoods for recovering old floors.

Vertical grain, or quarter-sawed and flat grain or plain-sawed flooring is manufactured in hardwoods and softwoods. Vertical grain flooring shrinks and swells less than flat grain flooring. It is more uniform in texture and wears more evenly.

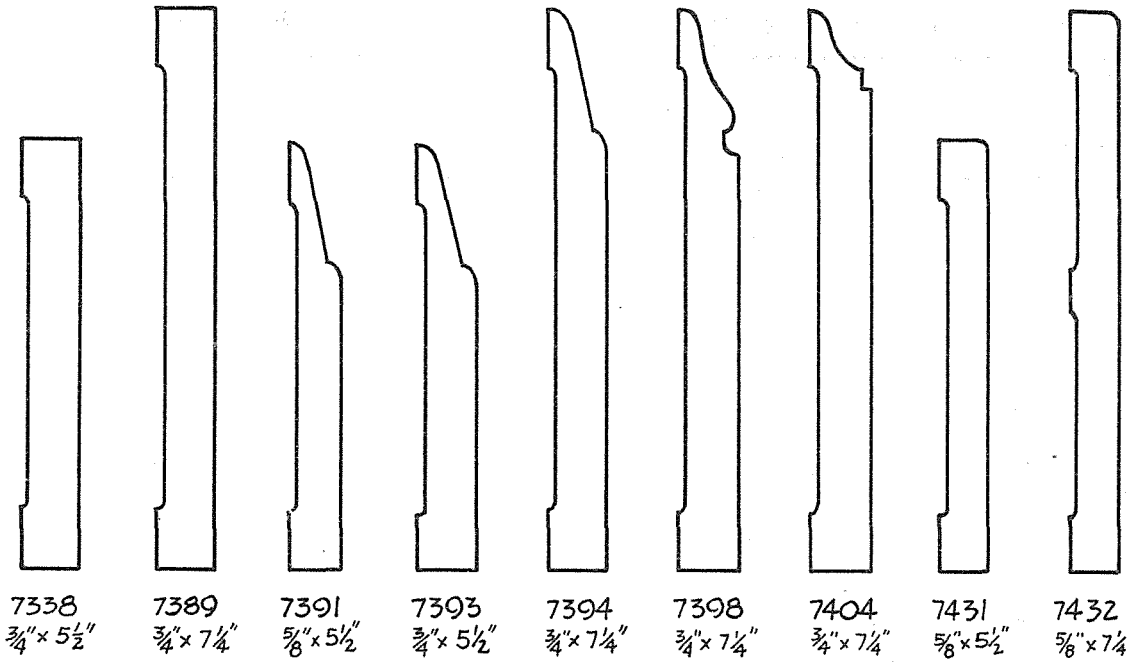
Softwood flooring is usually available in B and Better grade, C Select or D Select. The chief grades in maple are Clear No. 1 and No. 2. The grades in quarter-sawed oak are Clear, Sap Clear and Select. The grades in plain-sawed oak are Clear, Select and No. 1 Common.

63. Shingles

Shingles are made from western red cedar, southern cypress, northern white cedar and redwood. The shingle grades are as follows: western red cedar, No. 1, No. 2 and No. 3; southern cypress, No. 1, bests, primes, economies, and clippers; northern white cedar, extra star A star, standard star A star, and sound butts; and redwood, No. 1 and No. 2.

The western red cedar No. 1 grade, tidewater red cypress No. 1 and redwood No. 1 meet the requirements of the No. 1 grade of commercial standards as promulgated by the Department of Commerce. These highest grades, which are usually the most economical grades for permanent construction, are all clear, all heartwood, and all edge grain. Shingles that are all heartwood give greater resistance to decay than do shingles that contain sapwood. Thick-butt, narrow edge grain shingles are less likely to warp than flat-grain, thin-butt, wide shingles.

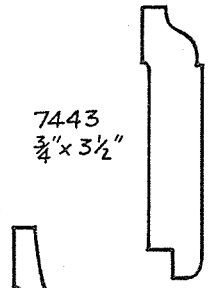
The standard thicknesses of shingles are described as 4/2, 5/2-1/4 and 5/2, meaning, respectively, 4 shingles to 2 inches of butt thickness, 5 shingles to 2-1/4 inches of butt thickness, and 5 shingles to 2 inches of butt thickness. Lengths may be 16, 18 or 24 inches. Random widths and specified widths, or "dimension" shingles are available in western red cedar, redwood and southern cypress. Random widths are available in northern white cedar. Random-width shingles are usually packed by the square, and dimension shingles by the thousand.



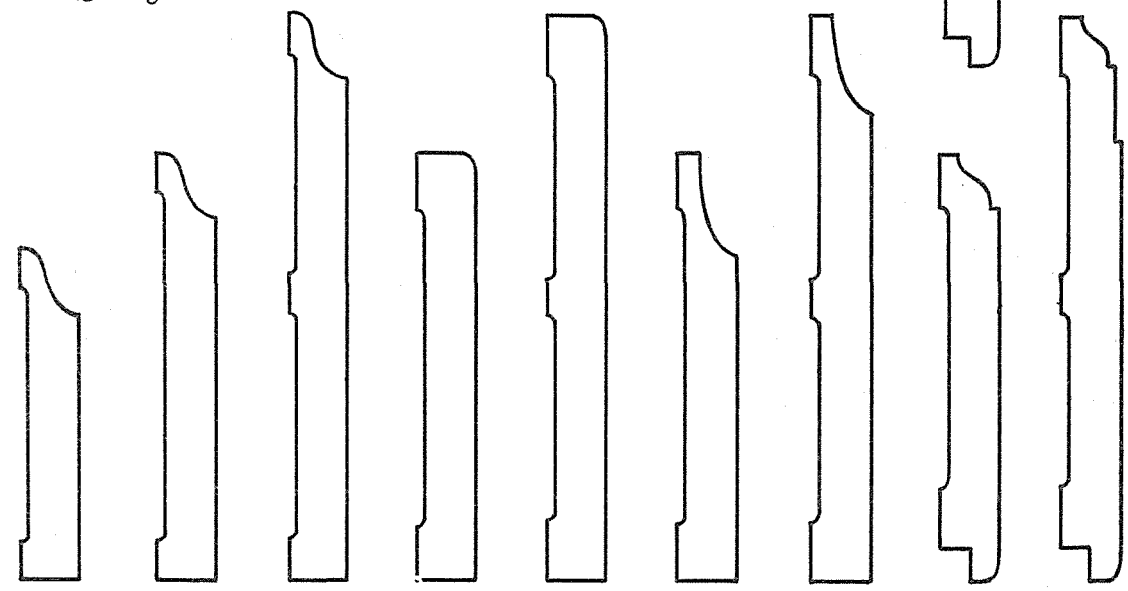
7338 3/4" x 5 1/2"
7389 3/4" x 7 1/4"
7391 5/8" x 5 1/2"
7393 3/4" x 5 1/2"
7394 3/4" x 7 1/4"
7398 3/4" x 7 1/4"
7404 3/4" x 7 1/4"
7431 5/8" x 5 1/2"
7432 5/8" x 7 1/4"

SHOE MOLDING

7445 1 1/16" x 1 3/8"



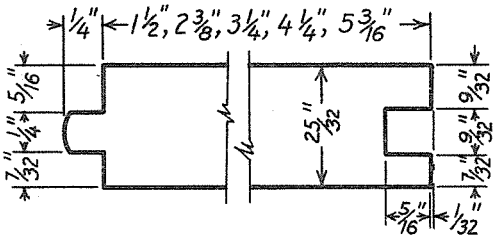
7443 3/4" x 3 1/2"



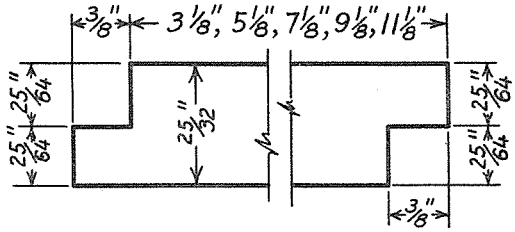
7385 3/4" x 4 1/4"
7386 3/4" x 5 1/2"
7387 3/4" x 7 1/4"
7434 3/4" x 5 1/2"
7435 3/4" x 7 1/4"
7440 3/4" x 5 1/2"
7441 3/4" x 7 1/4"
7446 3/4" x 5 1/2"
7444 3/4" x 7 1/4"

BASE BOARDS

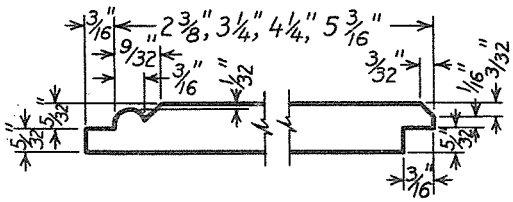
STANDARD INTERIOR TRIM



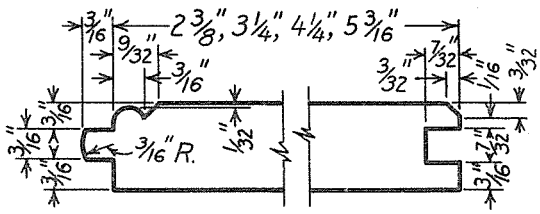
1-INCH FLOORING
Standard Matched



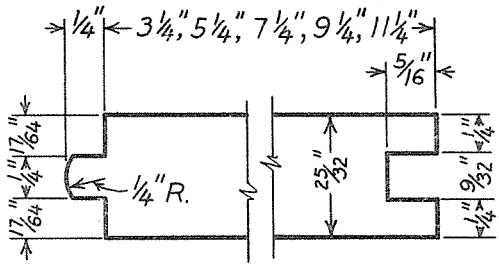
1-INCH SHIPLAP
½" Lap in some woods.



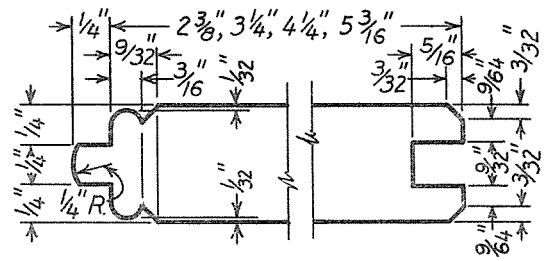
5/16-INCH CEILING
Shiplapped Pattern



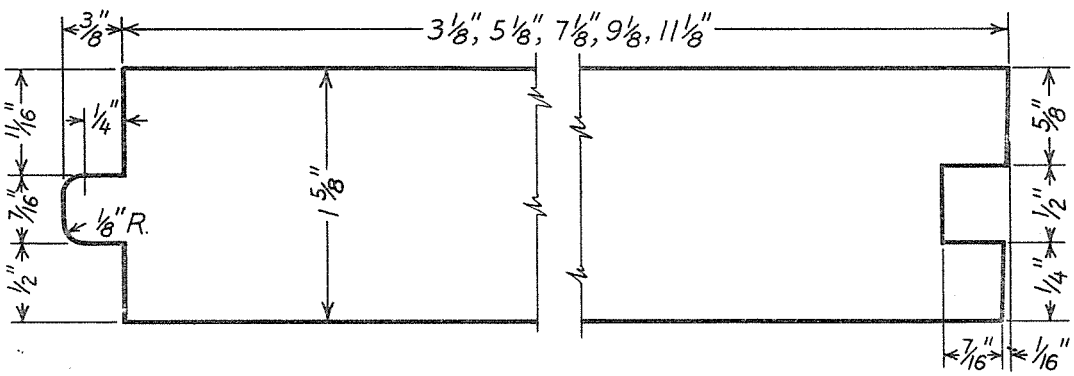
1-INCH CEILING
Dressed and matched pattern



1-INCH SURFACED TWO SIDES
AND CENTER MATCHED
S2SCM

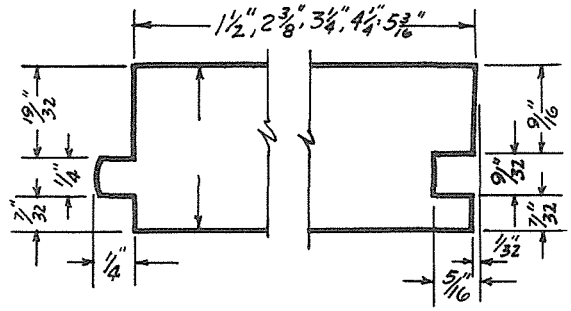


¾-INCH PARTITION

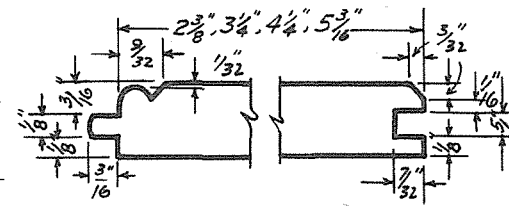


HEAVY FLOORING, DECKING OR ROOFING
Center Matched

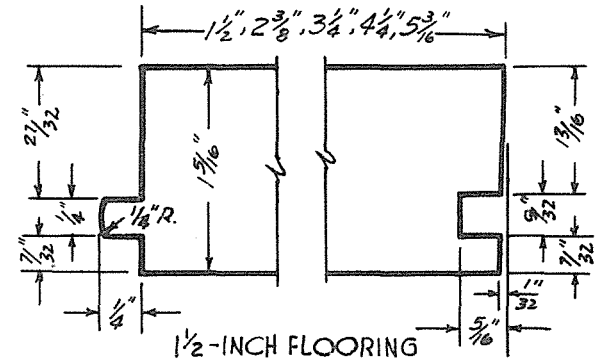
CLASSES, SIZES, AND PATTERNS OF YARD LUMBER



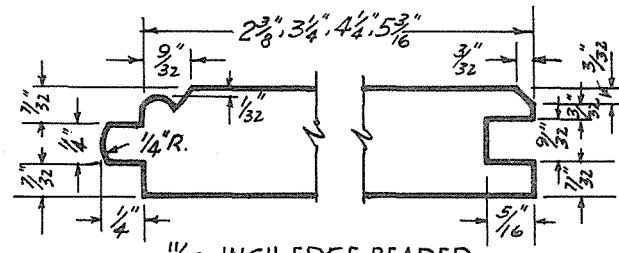
1¼-INCH FLOORING



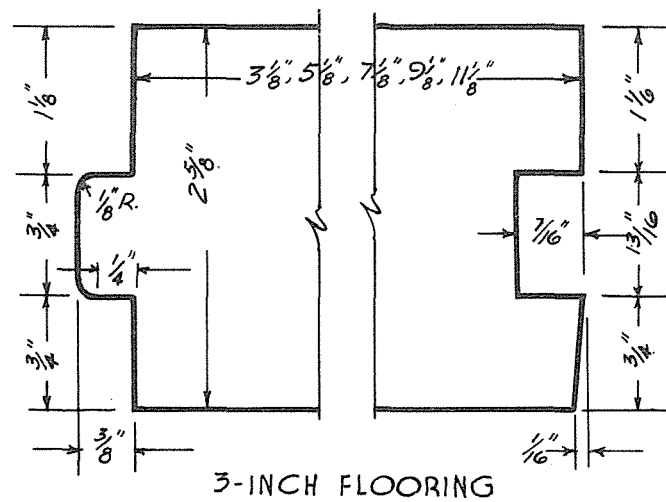
7/16" EDGE BEAD CEILING



1½-INCH FLOORING

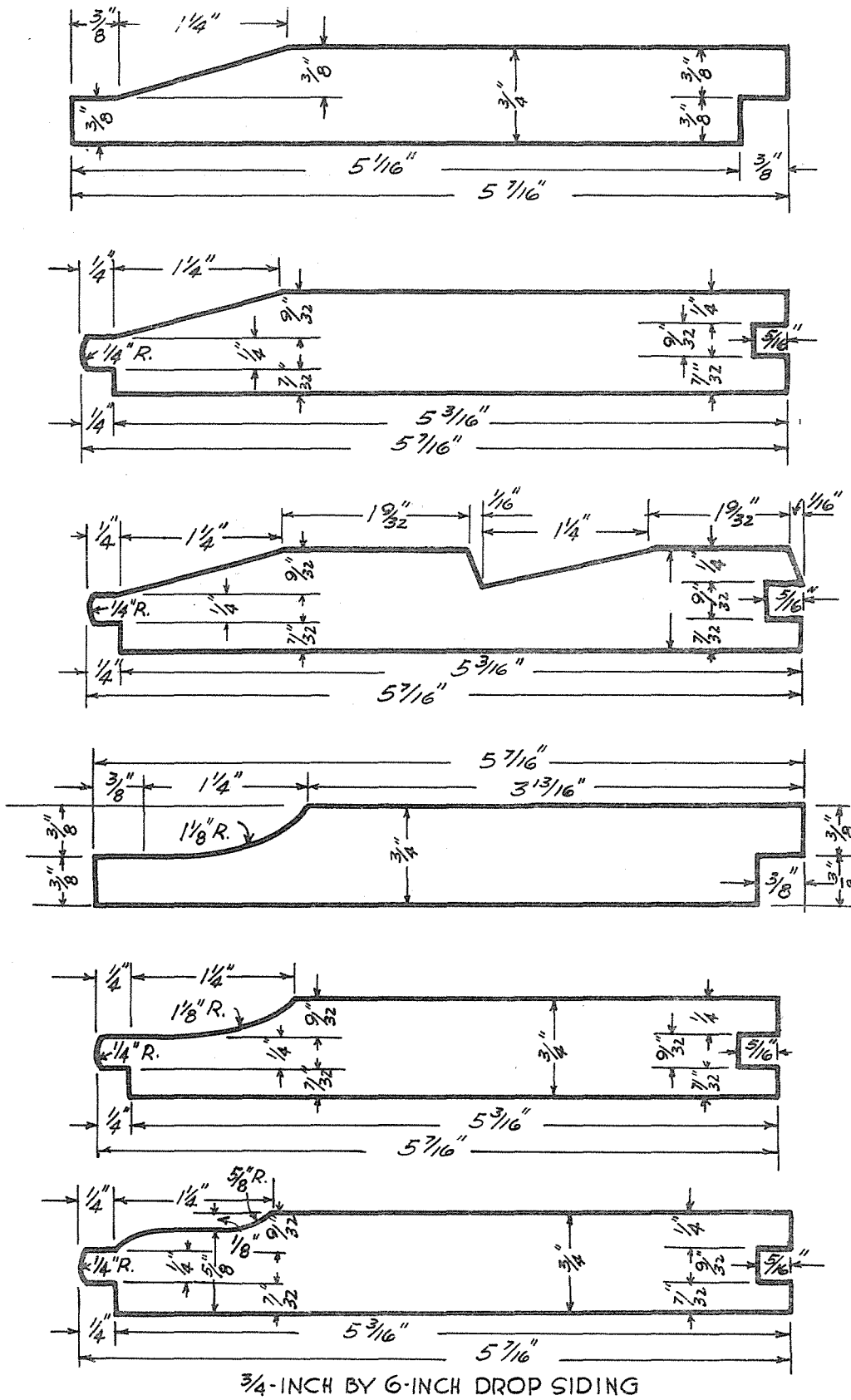


11/16-INCH EDGE BEADED CEILING



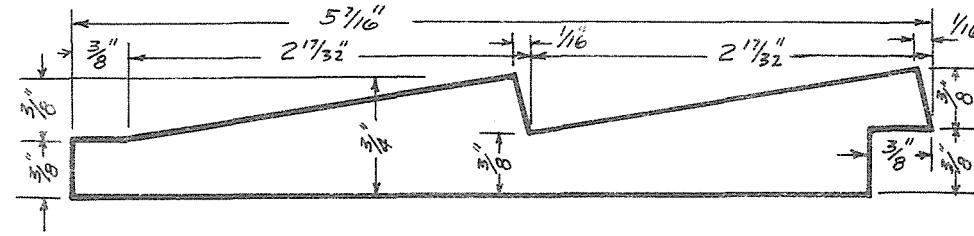
3-INCH FLOORING

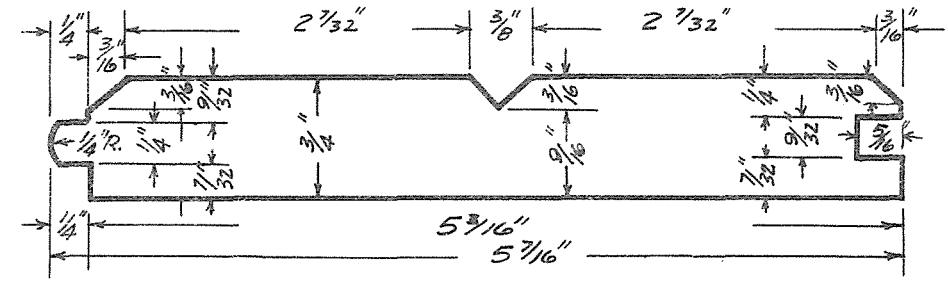
CLASSES, SIZES AND PATTERNS OF YARD LUMBER

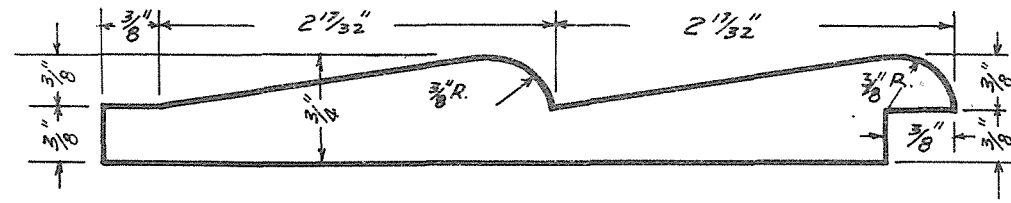


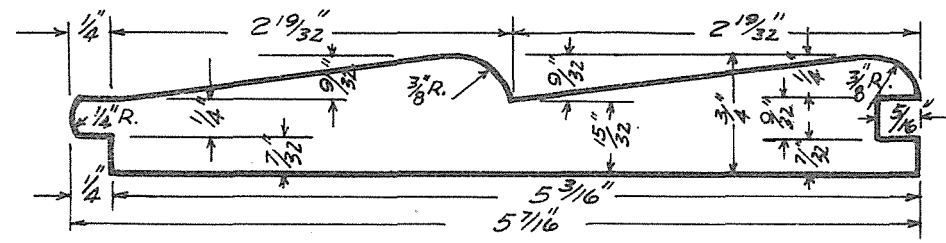
3/4-INCH BY 6-INCH DROP SIDING

CLASSES SIZES AND PATTERNS OF YARD LUMBER

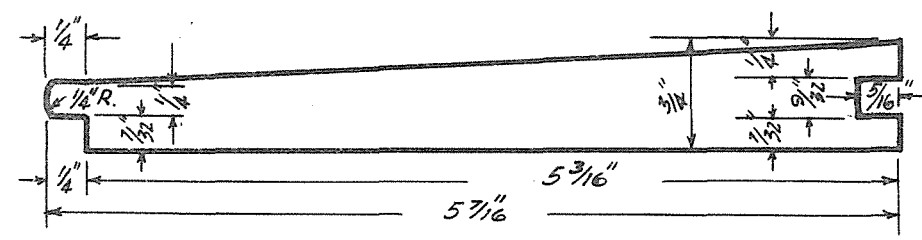


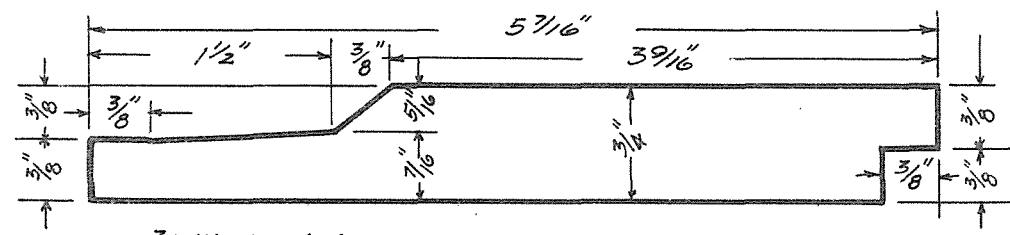






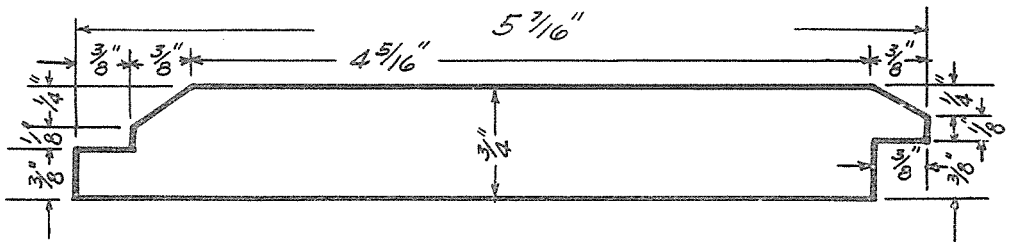
3/4-INCH BY 6-INCH DROP SIDING

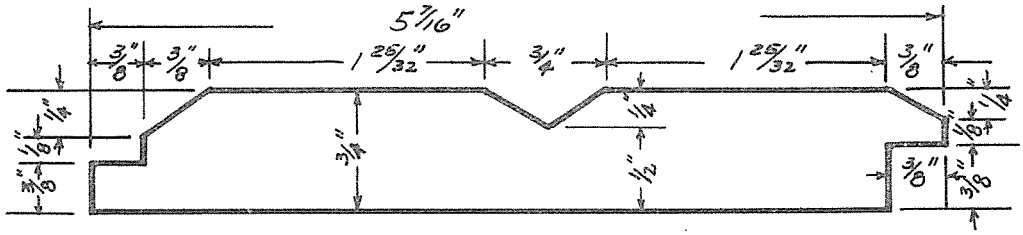




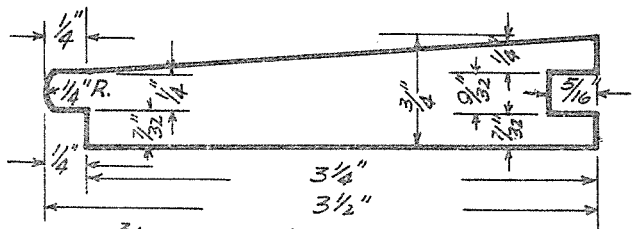
3/4-INCH BY 6-INCH DROP SIDING & RUSTIC.

CLASSES, SIZES AND PATTERNS OF YARD LUMBER

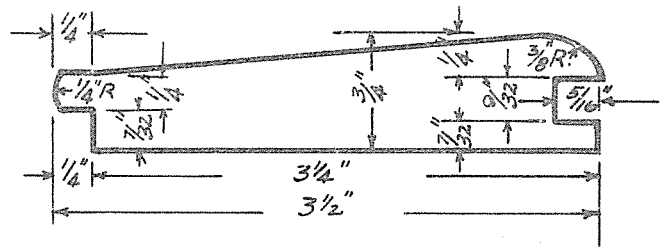


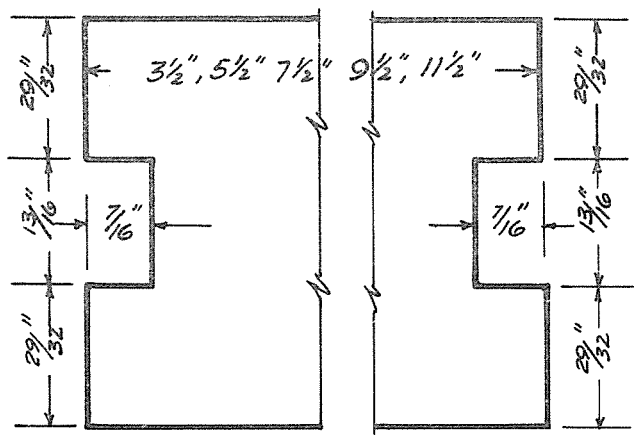


3/4-INCH BY 6-INCH RUSTIC



3/4-INCH BY 4-INCH DROP SIDING





3-INCH FLOORING GROOVED FOR SPLINES

CLASSES, SIZES AND PATTERNS OF YARD LUMBER.

64. Grade-Marked Lumber and Moisture-Content Provisions

Grade-marked and trade-marked lumber is available in certain species and items. Each piece of such lumber is stamped with its proper grade, with a number identifying the mill where it is made, and with the mark of the lumber association promulgating the grading rules.

The grade designation stamped on a board indicates the quality at the time the piece was graded. Subsequent exposure to unfavorable storage conditions, improper drying or careless handling may cause the material to fall below its original grade.

Lumber may be purchased under moisture-content provisions. The allowable moisture content is lower in the thinner material and in the select grades. In one specification for kiln-dried 4/4 inch and 5/4 inch lumber of C and Better quality, the moisture content must not exceed 12 percent in 90 percent of the pieces, and the remainder must not exceed 15 percent moisture content. For thicker select lumber and for kiln-dried boards and dimension, the allowable moisture-content values run up to 15 percent for 90 percent of the pieces and 18 percent for the remainder. Specifications for air-dried lumber are expressed similarly, but the allowable moisture-content values are higher, ranging from 16 percent and 19 percent for 4/4 inch C and Better up to 19 percent and 22 percent for 8/4 inch dimension. The "Wood Handbook" of the Forest Products Laboratory, gives further information on this subject.

65. Points to Consider when Ordering Softwood Lumber or Timber

The following excerpt from a Federal specification lists some of the points to be considered when ordering softwood lumber or timber:

1. Quantity: Feet, board measure, number of pieces if of definite size and length, etc.

2. Size: Thickness in inches - nominal and also actual if surfaced on faces. Width in inches - nominal and also actual if surfaced on edges. Length in feet - may be nominal average length, limiting lengths, or a single uniform length.

3. Grade: No. 1 Dimension, B and Better, etc., as indicated in grading rules of lumber manufacturers' associations.

4. Species of Wood: Douglas fir, southern cypress, etc.

5. Product: Flooring, siding, timbers, boards, etc.

6. Condition of Seasoning: Air-dry, kiln-dry, commercially shipping dry, etc. (Definite interpretation of requirements in this respect necessitates specifying in terms of moisture-content and how it is to be determined.)

7. Surfacing: Indicate whether rough (unplaned) or dressed (surfaced) stock is desired. S1S means surfaced on one side; S2S means surfaced on two sides; S1S1E means surfaced on one side and one edge; S4S means surfaced on four sides.

8. Association rules: Southern Pine Association, Western Pine Association, etc.

9. Structural Material: Use grading rules in Wood Handbook - Forest Products Laboratory and Rules of National Lumber Manufacturers' Association and American Society for Testing Materials specifications.

10. A certificate of grade and moisture content of lumber furnished by seller shall be given with large orders or otherwise, where the expense of inspection warrants.

66. Wood By-Products and Substitutes - When to Use

Many wood by-products can be used to advantage in buildings and structures. These by-products include papers, linoleum floor coverings, wall boards and insulating material.

Many of the wall boards on the market are made of a wood or by-products of wood. Masonite, Nu-Wood, Du-X, Ply-wood, Fir-Board and Firtex along with some others not mentioned, are generally accepted as suitable linings for some buildings.

Linoleums, because of their being to some extent manufactured from wood by-products, should receive consideration as floor coverings for kitchen and bathroom floors, office floors and the like.

Where thermal insulation is required in Forest Service buildings, the materials considered for the purpose should first include those of wood or by-products of wood. Besides sawdust and planer shavings, there are commercial insulators such as Balsam Wool, Balsam Wood Blanket, Redwood Bark Fibre, Insulation Boards, etc.

Information on thermal insulation may be obtained from bulletins prepared by the Bureau of Standards, U. S. Department of Commerce, the "Wood Handbook" of the Forest Products Laboratory, and other references quoted in the "Wood Handbook" on Pages 305 and 306.

Some simple applications of insulation are illustrated by the following:

Where dwellings or offices are used in the winter, the interior heat melts the snow from the eaves. An accumulation of ice backs the water above the eaves and often results in the formation of ice under the shingles. Water finally gets through the roof and causes trouble. This condition can usually be remedied by putting a strip of tarred paper under the shingles. The strip should run parallel with the eaves, with its lower edge at the edge of the eaves.

The use of paper, up 42" or more from the eaves, should be standard practice. The sheathing under tarred paper should be of 1" matched lumber or of 1" shiplap and laid solid.

Paper should be used between rough and finished siding. It will prove of value in preventing condensation in outside frame walls if used under the plaster or wall boards, or between the studs.

Sawdust or planer chips may be used for insulation over ceilings. The recommended plan is to use clean, dry sawdust and fill between the ceiling joists to a depth of three inches, leveling the material carefully. All wiring shall be protected with a wrapping of sheet asbestos. After the sawdust or planer chips are placed, one pound of borax should be sifted over every 10 square feet of exposed sawdust. This will help to make the sawdust fireproof.

References:

Wood Handbook, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.

Bulletins, Bureau of Standards, Department of Commerce.

Publications, National Lumber Manufacturers' Association.

Pencil Points Data Sheets.

CHAPTER IX - MILLWORK

67. General.

The term "Millwork" is generally considered to include all items of building material which are made of finished wood. Flooring, ceiling, siding and furring are made of finished material, but are not included under this heading. Although most millwork is manufactured in plants built especially for this purpose, some of it is made on the job as the need arises.

68. Classes of Millwork.

Modern manufacturing methods have so improved the quality of millwork that it is seldom necessary to design any special item which is to be included in a building. Special items can be made, but the increased cost does not usually warrant their use. All millwork which is selected should be of good design, sound construction and of dependable material. Several patterns of standard millwork are illustrated and described in Chapter VIII.

69. Importance of Proper Drying.

Wood shrinks and swells with each change in the moisture content below the fibre saturation point of the species. This adjustment takes place regardless of the type of finish used, but can be controlled within reasonable limits. Wood contains absorbed water and free water. When a piece of wood becomes soaked, the water is first absorbed by the cell walls to the point of saturation, and then the cell cavities fill with water. If the wood is dried, the free water is driven out first, leaving the absorbed water which can never be entirely driven out. The saturation point of the fibre is reached just before the absorbed water is driven out of the cell walls. It is very essential that the person in charge of drying lumber be able to determine the amount of moisture in the wood at any time, and to know when it has reached the proper dryness.

A. Moisture Content of Wood.

Lumber from which millwork is produced should have a moisture content of approximately 6%. This helps to prevent an unusual amount of stress or strain due to the normal swelling which takes place during the summer season when the doors and windows of a building are open. There should be no excessive shrinkage in the winter when the air is artificially heated, if the lumber has the proper moisture content.

B. Proper Room Humidity

The ideal relative humidity for a room temperature of 70° F. is 50%. The average heated building is below 30% and often less than 20%. Wood continually takes on and gives off moisture; the amount depending upon the atmosphere with which it comes in contact. If new buildings are not properly ventilated, the green masonry and the freshly plastered walls will throw off enough moisture to bring the air in the building close to the saturation point. Instances have been noted where the relative humidity of a new building has risen to 90% and has continued at that high point for a number of days. Such a high relative humidity tends to cause an abnormal swelling of the seasoned or dry wood.

Unusual atmospheric conditions whould be guarded against while the millwork is being installed in buildings. In some cases the damage due to cracking, checking and rupture of glued joints is almost beyond repair. Even though woodwork and cabinet work may be of the very best quality and workmanship, they can not stand up under unfavorable conditions of too much or too little humidity.

It is not an easy matter to lay down definite rules for controlling humidity because of the general lack of knowledge as to the need for facilities to improve the moisture content. There are on the market only a limited number of devices to correct the trouble. There are available a number of mechanical humidifiers which automatically maintain the proper humidity under varying conditions. It may be impracticable to use any of these, but if a hygrometer is used to determine the humidity, the atmospheric conditions may be improved by evaporating water where additional moisture is required, or by opening windows or doors where there is too much moisture in the air.

C. Storage of Millwork

Certain precautions must be taken by those whose duty it is to store millwork. The storage of millwork against outside walls should be avoided in extremely cold weather. The dampness of the air caused by condensation may cause trouble. The rays of the sun should not be allowed to strike the unfinished wood. Lack of care may cause the raising of the grain in lumber. This is, in itself, not serious, but it detracts from the appearance. Millwork should be stored where artificial heat is available to maintain the moisture content at the value corresponding to conditions in use.

70. Woods Used for Millwork

A careful reading of Chapters VII and VIII will aid in the proper selection for millwork products. The wood chosen should be appropriate for the architectural problem and for the service it is to render. Bright, clean, stain-free stock is highly desirable for any use requiring a natural finish. If the wood is to be covered, stained or painted, stained stock may be used if it is free from decay.

71. Millwork Specifications

Lumber for millwork should be chosen so that it may be used economically for the purpose it is to serve. Information will be found in Chapter VIII which will guide in the selection of lumber by grades. The designer should be sure that he is listing material of the proper size and make-up when selecting stock patterns of moldings, etc. Materials are frequently listed under "nominal thickness" instead of "final thickness". As a result, those buying materials may not be getting what they anticipated.

The designer is necessarily interested in contour in a design and depends upon moldings to produce the characters desired in the finished product. Therefore, the moldings and lumber sizes should be furnished in accordance with the details shown on the plans so that the design can be carried out properly. Designs should be made to serve the best in utility and be the least excessive in the use of material. They should be in keeping with good principles of architectural design. Sufficient details should be shown on the plans to clearly picture and design the work. The specific description should be a part of the specifications where standard designs are to be used.

72. Plywood and Veneer

A. General

The Forest Service Wood Handbook defines plywood as, "a piece of wood made of three or more layers of veneer joined with glue and usually laid with the grain of adjoining pieces at right angles." The purpose of plywood is to redistribute the strength of the wood by cross-banding the pieces of which it is composed. The greatest strength is obtained when odd numbers of pieces are used. The greater the number of pieces the more homogeneous are the properties of the finished product.

The veneer of which plywood is composed is produced in one of three ways: rotary cutting, slicing or sawing. In the types of construction where veneer is used, it is desirable that all the veneer used on the job should be produced by the same method. Rotary cut veneer should not be mixed with sliced veneer or sawed veneer. When the different types are mixed, unequal stresses are set up and the resulting product is not satisfactory.

It was formerly thought that the use of veneer cheapened the product, but modern methods of production have dissipated this idea. Veneer eliminates splitting, checking and warping of broad surfaces. For these reasons it is very valuable in the manufacture of furniture, doors, panel work, etc.

B. Rotary Cut Veneer

Rotary cut veneer is produced in a continuous strip by rotating a log against the edge of a knife. It may be produced in any width, depending upon the length of the log or bolt. The wood is softened by steaming or boiling for several hours. It is then fastened in a lathe and rotated while a knife is automatically pressed against it in order to peel off a veneer of the desired thickness. The thickness varies from 1/120 to 7/16 of an inch, depending upon the species of wood from which it is prodeced. Most of the veneer used for manufacturing purposes is produced by this method.

C. Sliced Veneer

Sliced veneer is made by fastening a log, bolt or flitch in a lathe and then moving it up and down with a diagonal stroke before a heavy knife. This method of making veneer is used in cutting quartered oak and other material where a beautiful grain is desired. Very thin sheets may be produced.

D. Sawed Veneer

This veneer is cut with a circular saw of special design. The saw is usually about 1/20 of an inch thick at the edge and gradually becomes thicker on one side toward the center. The thin edge produces a thin saw cut, while the thicker center gives rigidity and strength to the saw. Slices of veneer cannot be cut as thin by this method as by either of the other two, but either side of the slice will be satisfactory for panel work. The logs or bolts do not have to be softened before being cut by this method.

73. Exterior Millwork

Exterior millwork includes practically all of the material used on the outside of the building. As a general rule, material that is surfaced but not molded is excluded. The species of wood most generally used are Southern pine, Douglas fir, redwood, red cedar and cypress. Details of exterior millwork are illustrated on Pages 104 to 112 inclusive.

A. Entrance Frames

In the construction of a dwelling, the entrance is usually highly detailed. Entrances should be made of wood with fine painting qualities and maximum resistance to decay, and the sills should be made of oak. Oak sills should be specified for all exterior frames where wood is to be used. Practical entrance frames are adaptable to the use of stone or concrete sills. This fact should be taken into consideration in the design so that certain parts of the frame

may be removed or cut off to provide for a change, if such is necessary on the job. In some cases, metal flashing should be used at sills.

B. Door Frames

The design of door frames should correspond to the design features that appear on window frame details used with them. This applies particularly to outside casings and drip-cap members. The wood sill is eliminated in masonry construction, and the jambs of the frame end on top of the stone or concrete sill. In other forms of construction the jambs extend to the bottom of the wood sill and are nailed into the sill ends. Typical door frame details are shown on Pages 104 and 105.

C. Window Frames

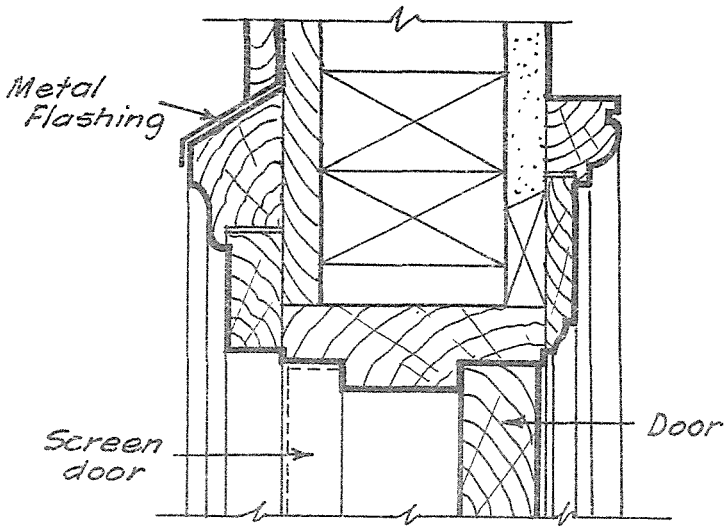
Window frames are among the most important articles of exterior millwork. Window frames are intended to close and finish an opening, to give a good architectural effect, prevent the infiltration of air and to provide a tight joint against water. They must serve as guides for holding the sash. They must be constructed to prevent leakage of air and water around the sash and yet allow the sash to be adjusted as desired. When window frames are furnished as millwork they usually come knocked down or in stock sizes and must be carefully assembled on the ground. Frames of special manufacture or of patented design may require special instructions for their assembly. Manufacturers generally furnish these instructions with their products. Typical details of window frames for various types of construction are shown on Pages 106, 107, 108 and 109.

D. Casement Frames

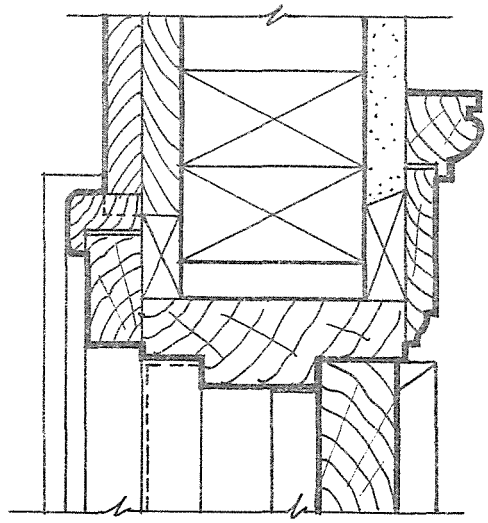
Two types of sash, swing-in and swing-out, are provided for casement frames. The swing-out type is recommended because it is more likely to be wind and water proof. This is true regardless of the type of building construction in which casement frames are used. The out-swinging casement sash closes from a rabbet on the outside. Both rain and wind must work their way along the sill, under the sash and over the rabbet to come through into the building. The depth of the stool which extends to the sash rabbet is an added safeguard and is desirable for appearance. Details of both types of sashes are shown on Pages 110, 111, and 112.

E. Windows and Sash

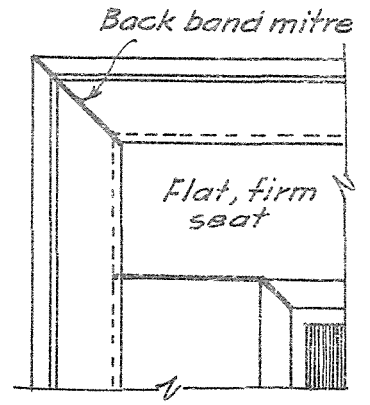
There is a great variety of sizes of windows and sash. Sash should be selected to afford the proper amount of daylight. They should be appropriate in design or make-up to fit the architectural requirements. The type of frame will have some bearing on their selection, whether they are chosen for casement or double-hung type of windows. Besides admitting light, a window must provide ventilation and at the same time act as a barrier against heat and cold.



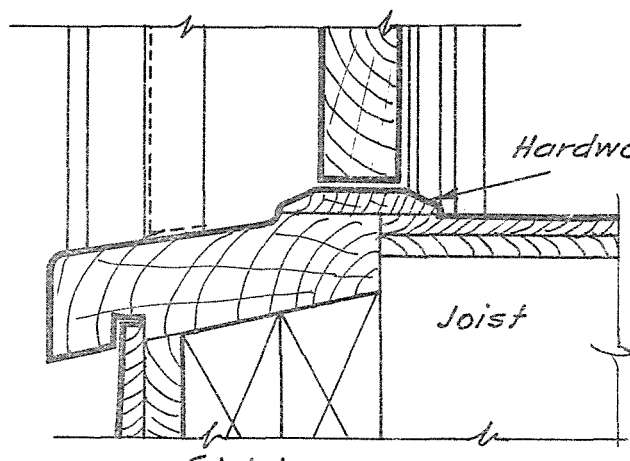
HEAD



JAMB

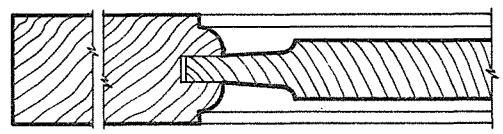


ELEVATION OF TRIM
Showing correct mitres

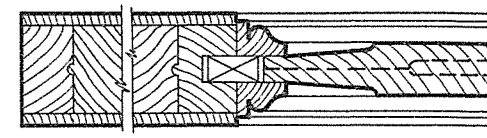


SILL

DOOR FRAME DETAILS

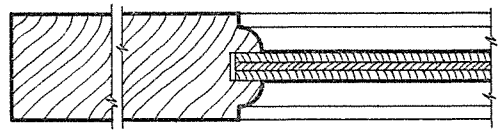


SOLID MOLDED DOOR STILE & PANEL



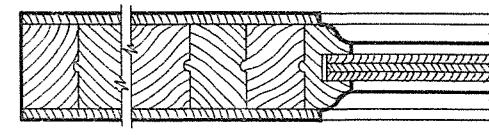
FLUSH MOLDED DOOR STILE

Veneer Construction

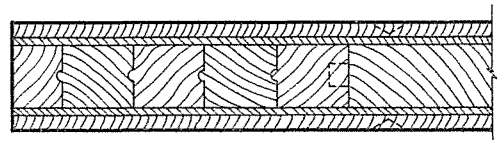


SOLID MOLDED DOOR STILE

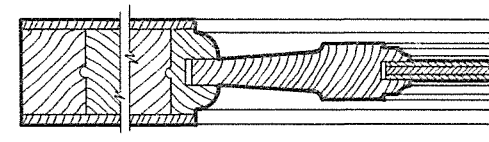
Veneered Panel



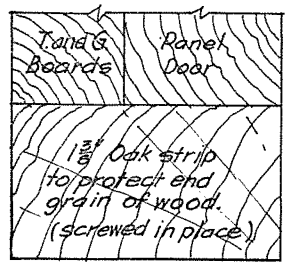
VENEERED STILE & PANEL



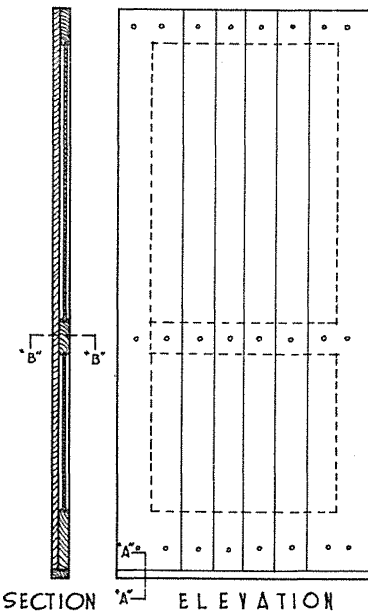
FLUSH VENEER DOOR



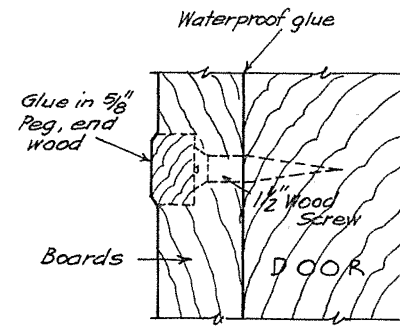
VENEERED PANEL SET IN INSERT



A-A DETAIL



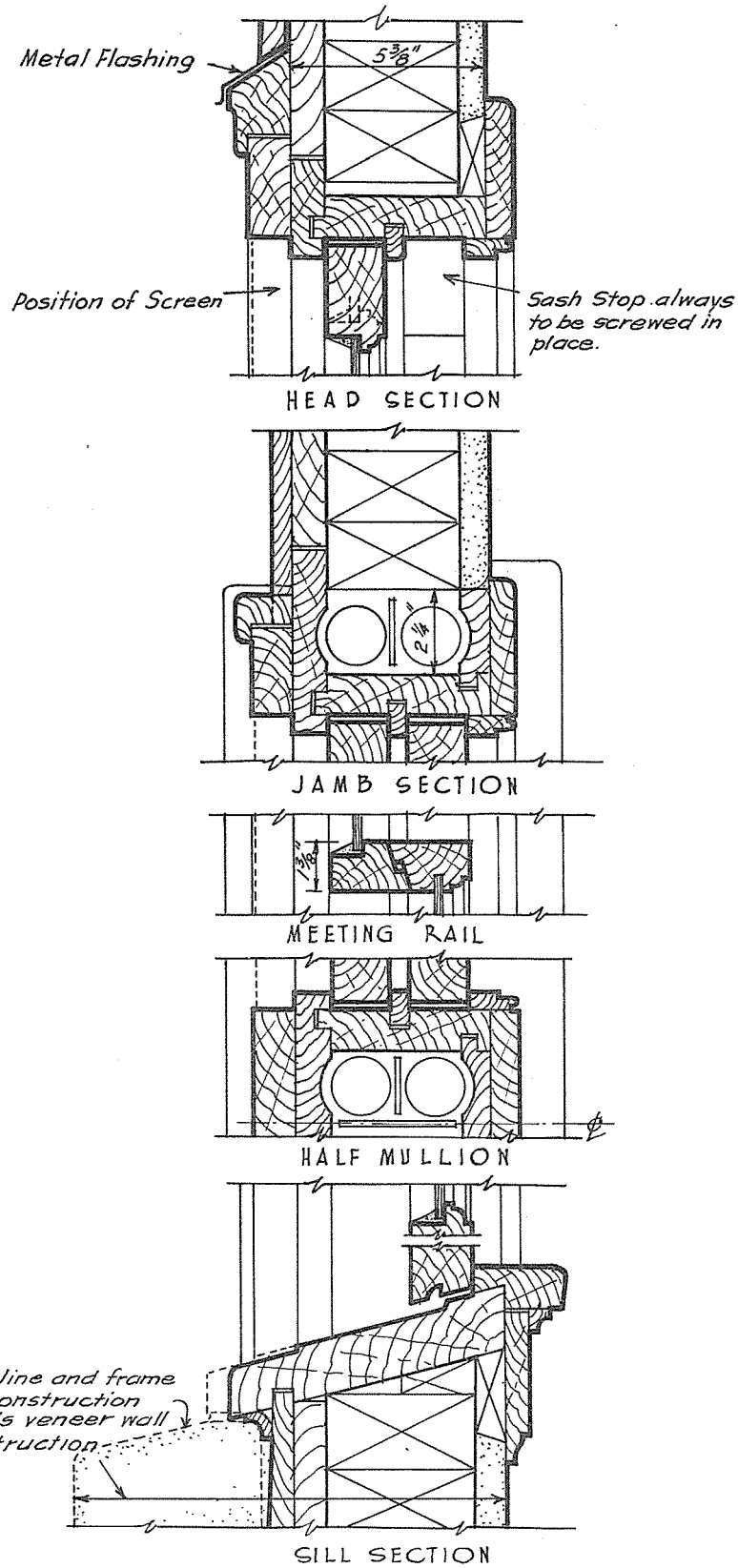
SECTION ELEVATION



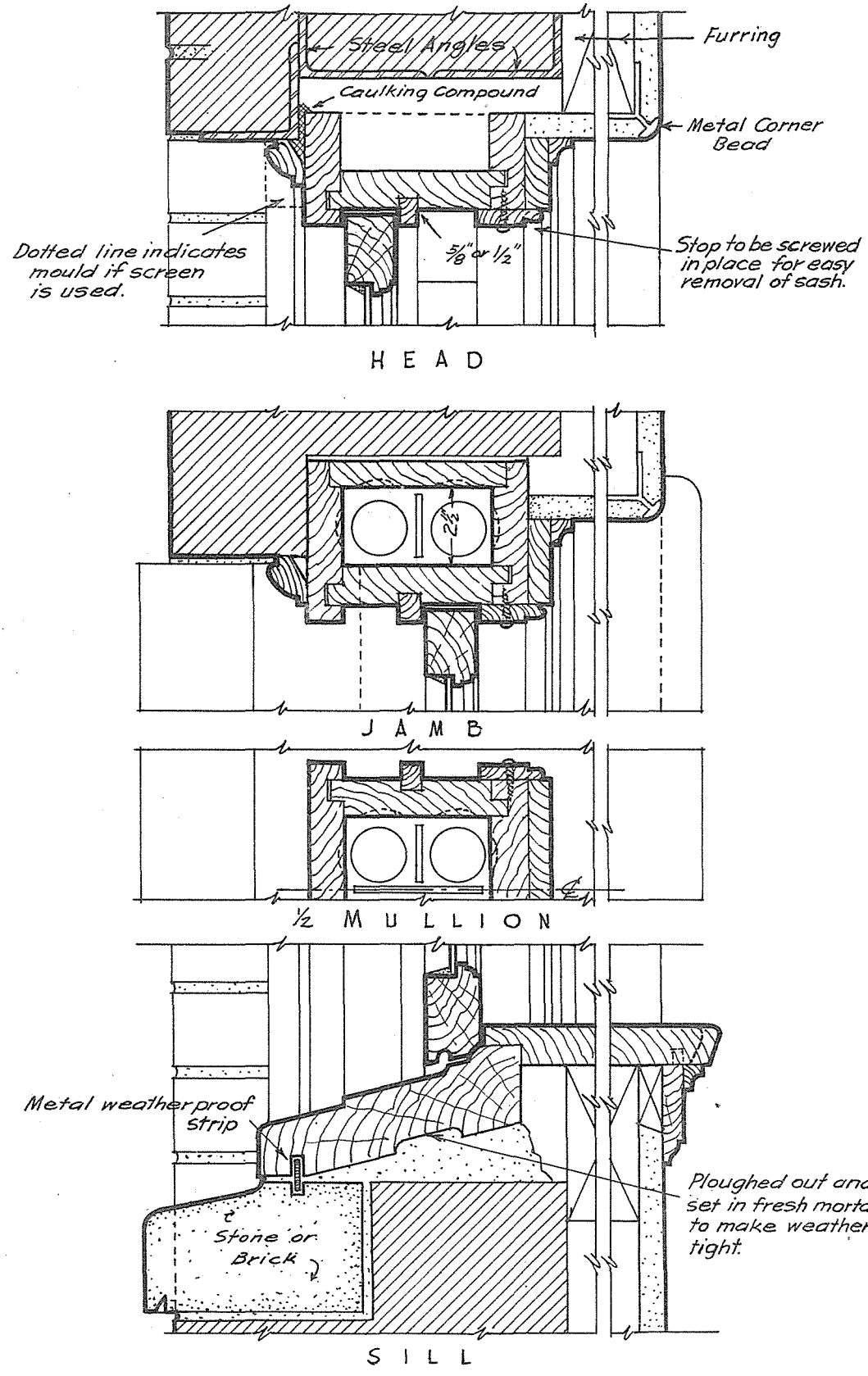
B-B DETAIL

NOTE: Ordinary Panel doors may be made to match knotty pine or cedar wall finish, by applying similiar boards to them.

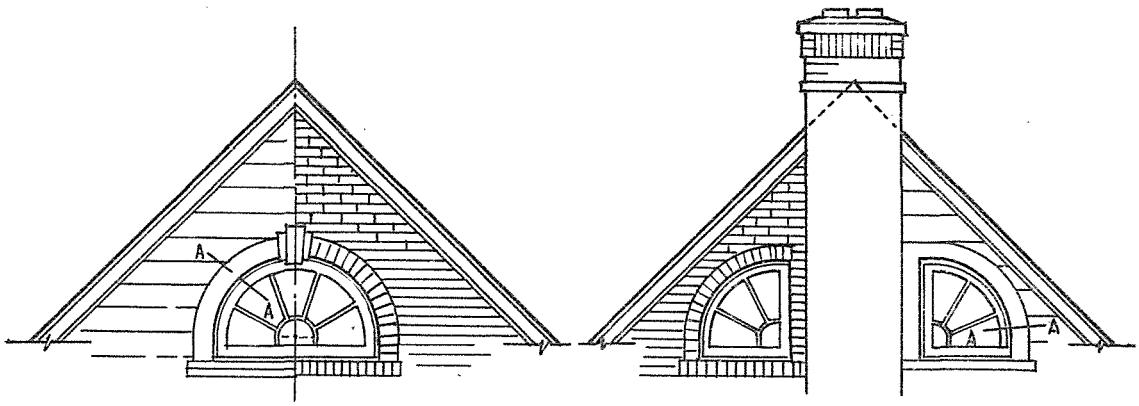
DOOR DETAILS



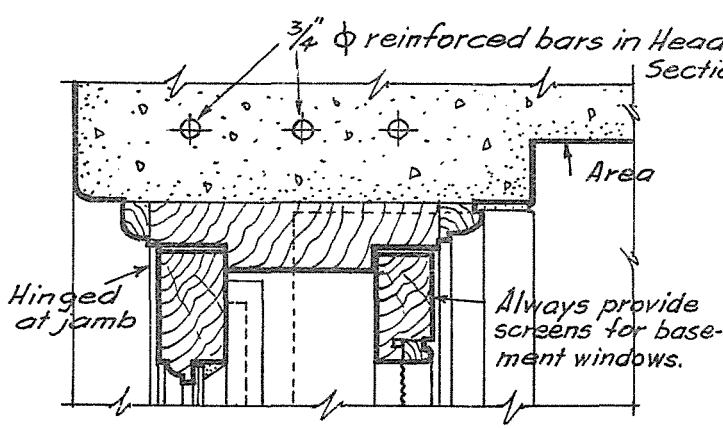
WINDOW DETAILS FOR FRAME WALL



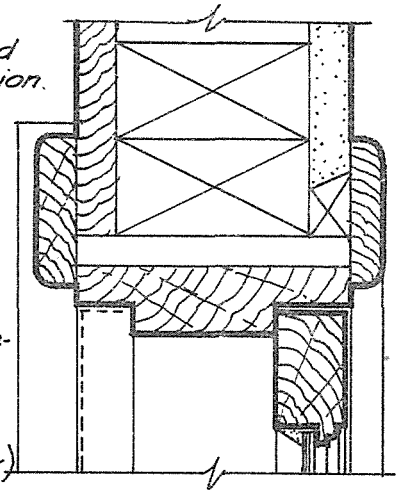
WINDOW DETAILS FOR MASONRY WALL



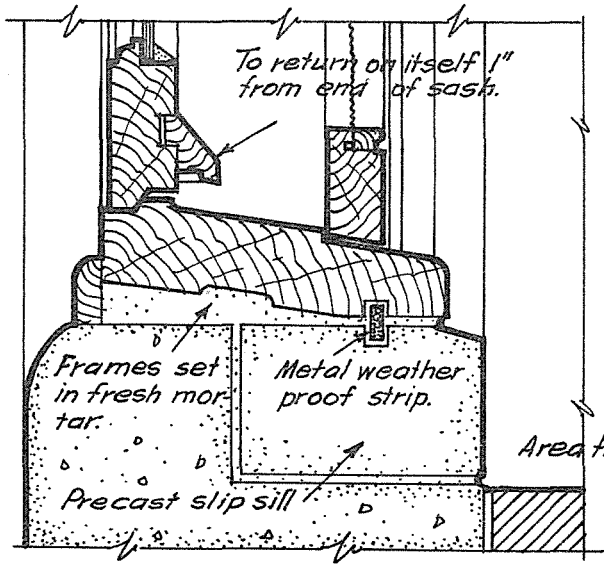
CIRCULAR SASH WINDOWS



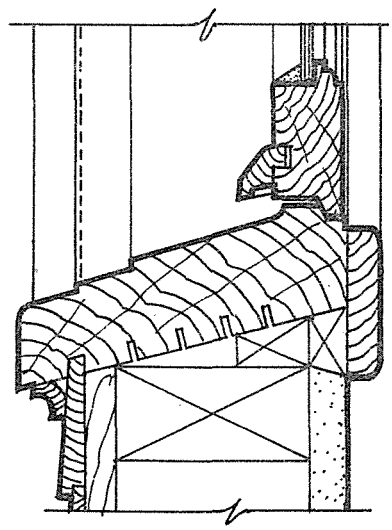
JAMB SECTION (Head Similar)



SECTION A-A

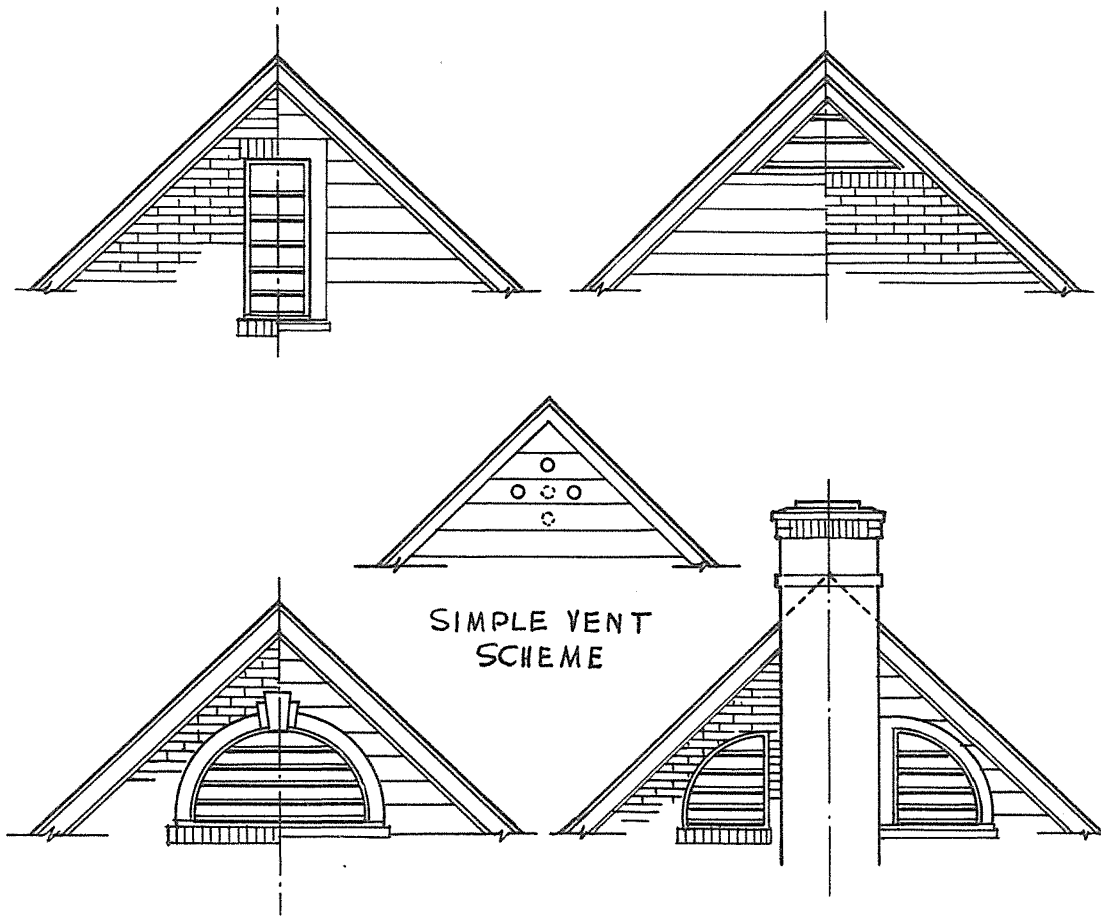


SILL SECTION
CELLAR WINDOW

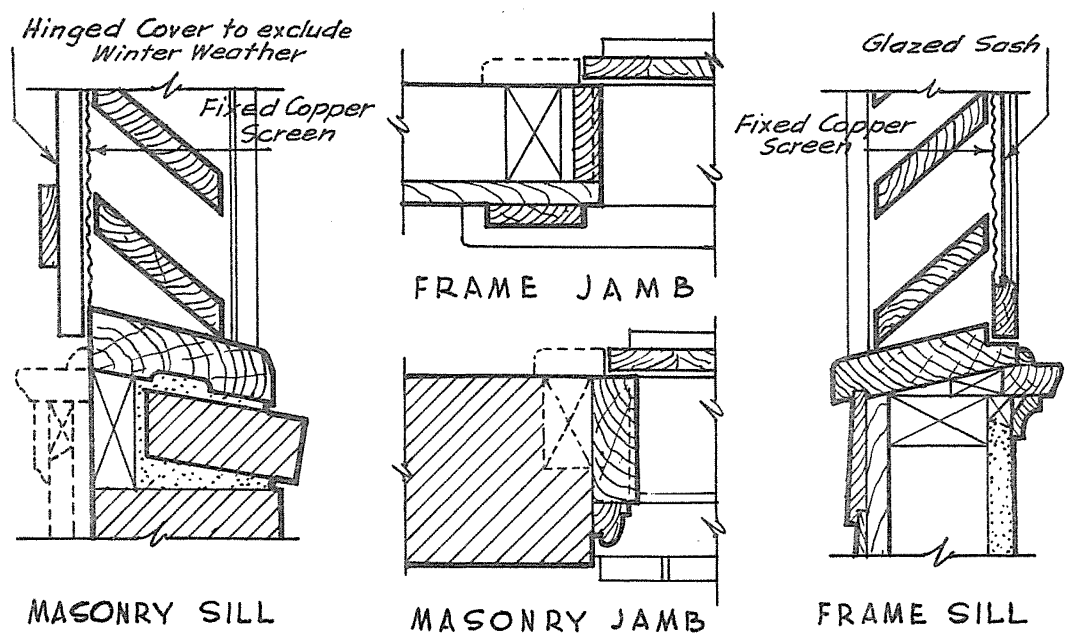


SILL SECTION
ATTIC WINDOW

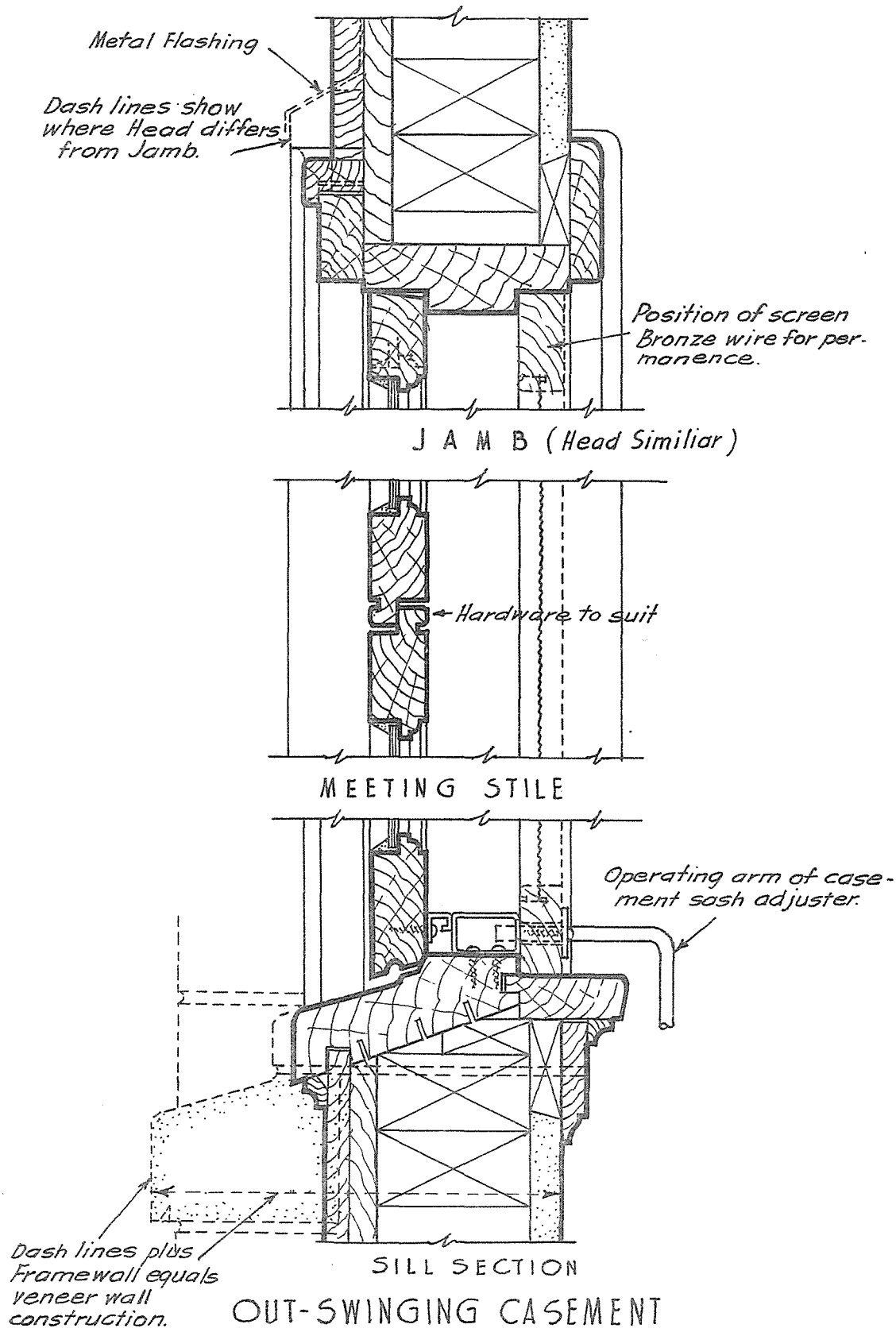
CELLAR AND ATTIC WINDOW DETAILS



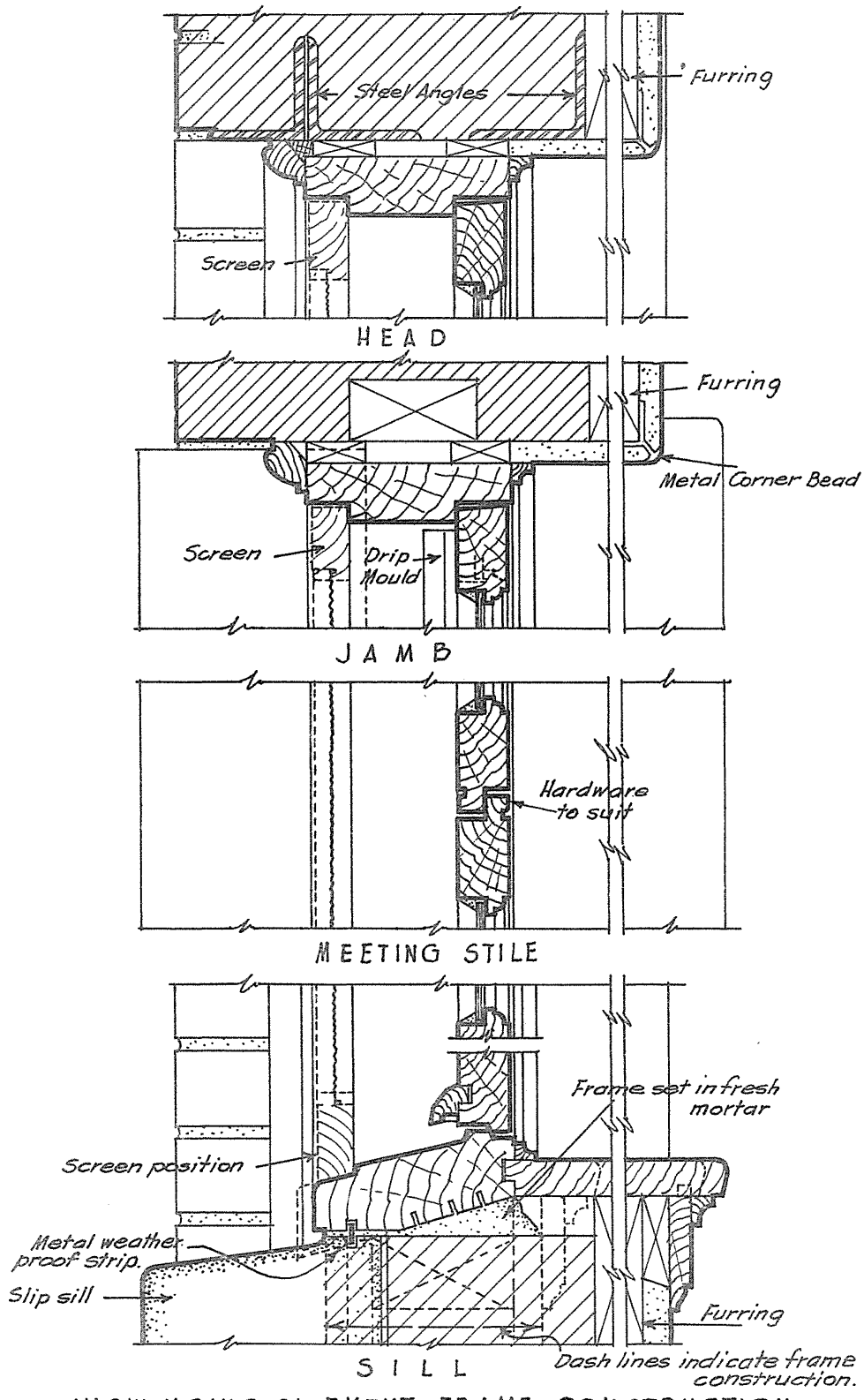
VARIOUS TYPES OF LOUVRE WINDOWS



LOUVRE DETAILS

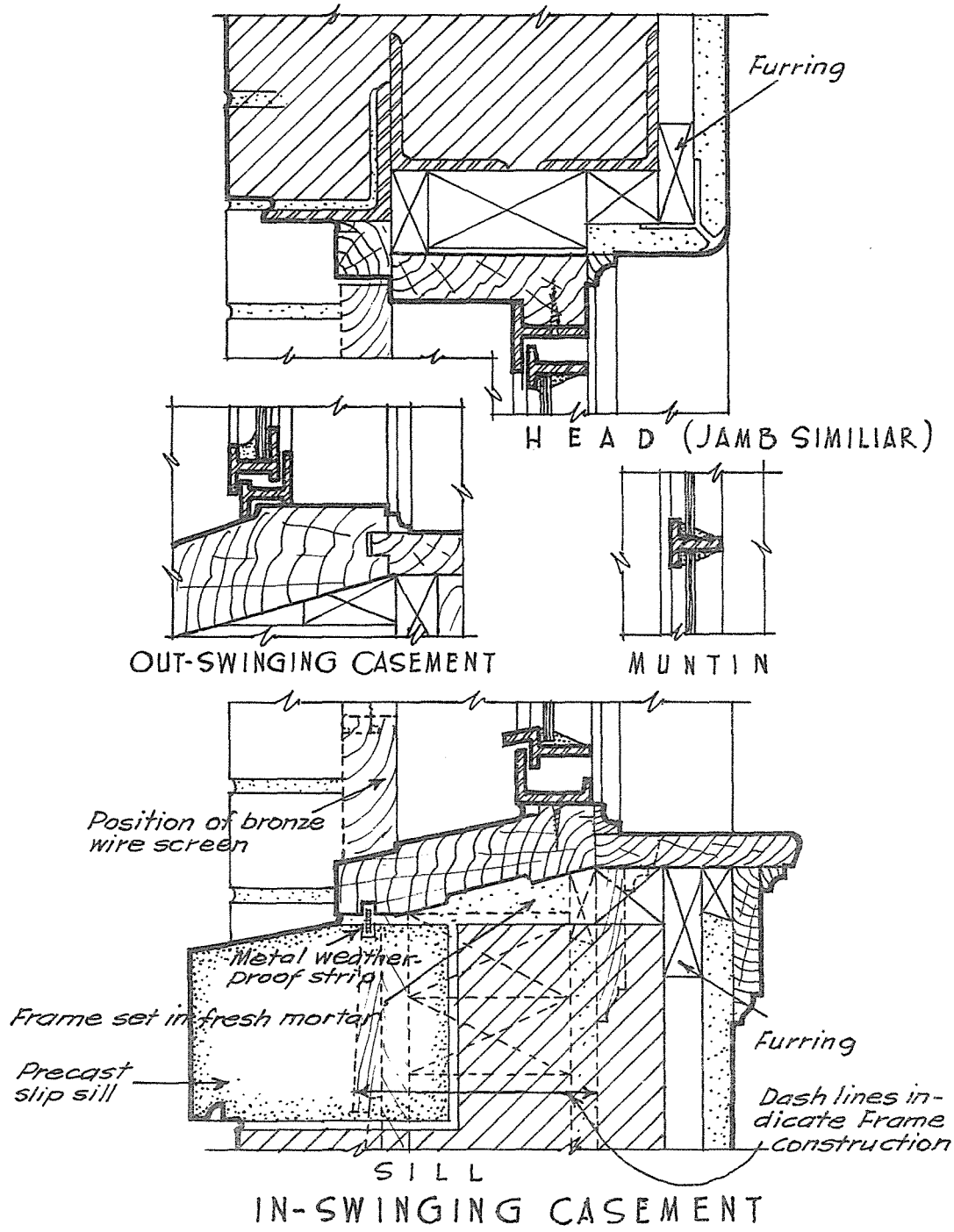

Metal Flashing
Dash lines show where Head differs from Jamb.
Position of screen Bronze wire for permanence.
JAMB (Head Similiar)
Hardware to suit
MEETING STILE
Operating arm of casement sash adjuster.
Dash lines plus Framewall equals veneer wall construction.
SILL SECTION
OUT-SWINGING CASEMENT

CASEMENT WINDOW FOR FRAME WALL



INSWINGING CASEMENT FRAME CONSTRUCTION

CASEMENT WINDOW DETAILS FOR MASONRY WALL



STEEL CASEMENT WINDOW DETAILS

Storm windows are extra outside windows and are of much value in reducing heat losses in places where excessive cold prevails.

The size of a window is the total size of the glass plus a certain number of inches in width and a certain number of inches in height, to cover the horizontal or perpendicular width of the wood which surrounds or divides the glass. As an example, the usual twelve light, double-hung window has 4½ inches of wood in a section cut horizontally through the window. This is made up of two muntin bars, each 1/4" wide and two stiles each 2" wide. Vertically this wood allowance is 6 inches and is made up of two muntin bars each 1/4" wide, a top rail 1-3/4" wide, a check rail 1" wide and a bottom rail 2-3/4" wide. These dimensions are for an exterior opening.

A check rail is formed where the bottom rail of the top sash meets the top rail of the bottom sash in a double hung window. Three types of check rails are commonly used; rabbeted, beveled and plain. The beveled and rabbeted check rails are considered to be the most satisfactory. These types of rails are indicated on Page 114.

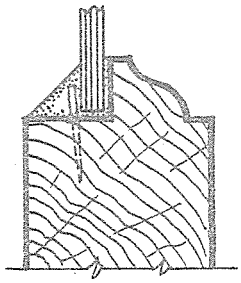
Bottom rails and stiles are first mortised and tenoned together and then cross-pinned with steel dowel pins. Other rails in the sash and window are tenoned into a slot in the stile and are likewise pinned together.

It is desirable to smoothly machine the groove for the sash cord and pulley, since this prevents frayed or broken sash cords. While there are in common use several methods of sash construction which vary in the details of the stiles and rails, manufacturers usually furnish details of their sash or dimensions of the openings which they fill. It is always well to specify in the plan, the size of the opening that the sash is to fill.

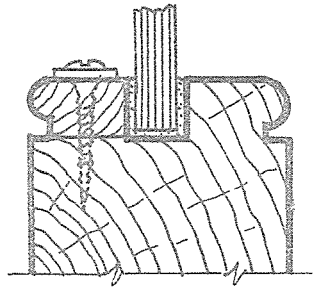
F. Other Exterior Millwork Items

In addition to the specified items mentioned exterior millwork includes cornices, moldings and porch material. Most of these pieces are of solid construction and should be carefully constructed of the most durable wood. Porch columns are often the most difficult pieces to build because of their size. They are usually built up of a number of pieces of material which are tongued and grooved and glued together.

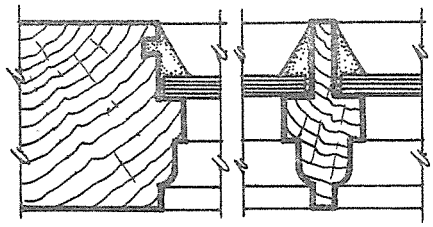
COMMON METHOD



GLASS SET WITH GLAZIERS POINTS AND PUTTY

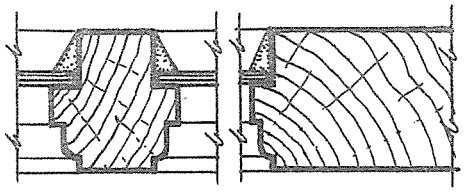


GLASS SET WITH LOOSE WOOD BEAD



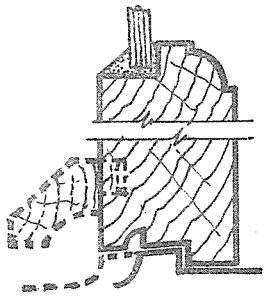
STILES & RAIL MUNTIN

Eastern Opening

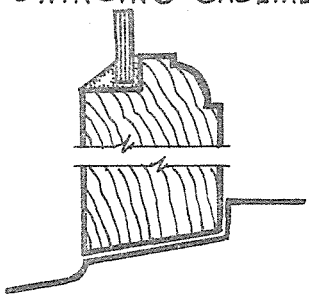


MUNTIN STILES & RAIL

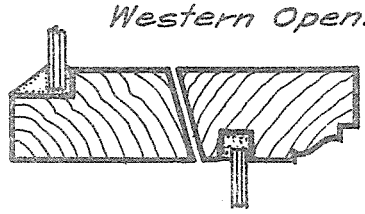
Western Opening



IN-SWINGING CASEMENT

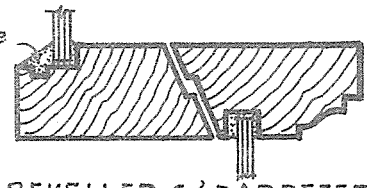


OUT-SWINGING CASEMENT

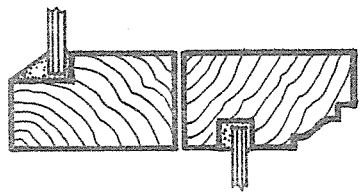


BEVELLED

Putty grove



BEVELLED & RABBETED



PLAIN

Note: All glass to be bedded in putty, sprigged, puttied and back puttied and made thoroughly weather tight.

SASH DETAILS

74. Interior Millwork

The term, "interior millwork", covers all of the wood used inside of a building, including built-in fixtures and cabinet work. Stock items are used in most construction, but some architects prefer to design their own millwork. Standardization has progressed to where attractive individual effects can be produced without special design. Doors have been more fully standardized than any other item of millwork, but standardization is rapidly increasing in other fields.

A. Doors

As stated above, doors are standard items and include only two general types which are classed as panel doors and slab doors.

A panel door is built up of stiles or upright pieces and rails or cross pieces which form a frame to enclose the panel, or panels. All parts of the door may be of solid or veneered material.

Slab doors are usually of veneered construction and consist of five plies. The inner ply is made of core material or small pieces of waste sash material which are tongued and grooved and glued together. Two cross-banded sheets of veneer are placed on each side of the center core to form an extremely solid piece of construction.

B. Panel Work

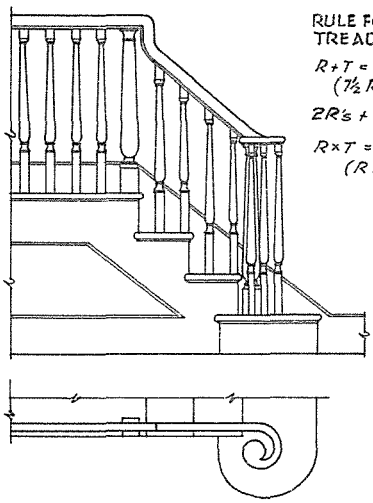
Panel work is built in a manner similar to door construction. There is very little standardization in panel work because of the wide variety of widths of spaces in which panel work is placed. For this reason each separate piece of panel construction is individually designed. Panel work consists of stiles and rails into which the panels are inserted. All parts are carefully machined to fit and may be put together and installed as a whole or built up as the work progresses.

C. Interior Trim

All material from which the items of interior trim are cut should be of well-seasoned stock to insure against checking, warping and twisting. Each piece should be free from stain, resin, pitch pockets and decay. Most trim is made from Southern pine, Douglas fir, oak, maple, birch or gum. A more detailed description of the kinds of material to be used will be found in Chapter VIII.

D. Stair Material

The construction of the various pieces used in building stairways has been standardized by a number of lumber manufacturers. This makes it easy for a designer to plan elaborate stairway details without causing additional expense by having each piece handmade. Standard stairway details are shown on Page 116 .



RULE FOR RISE AND TREAD OF STAIR:

$R+T = 17\frac{1}{2}"$ to $18"$

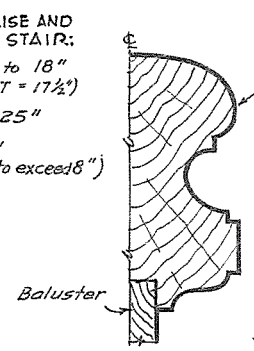
$(7\frac{1}{2}R+10T = 17\frac{1}{2}")$

$2R's + T = 25"$

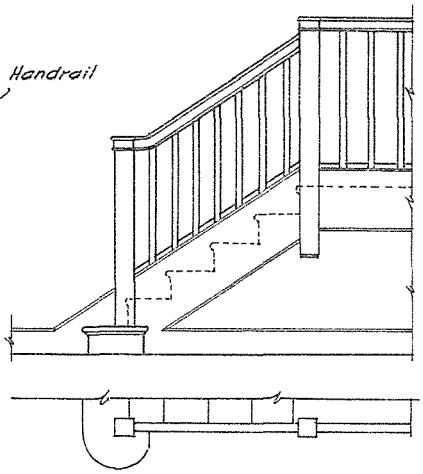
$R \times T = 75"$

(R not to exceed 8")

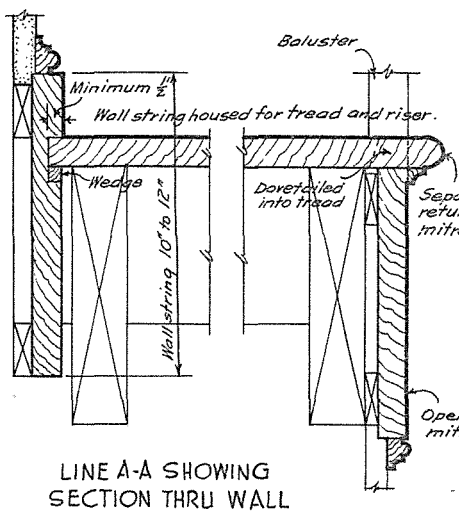
OPEN STRING STAIR



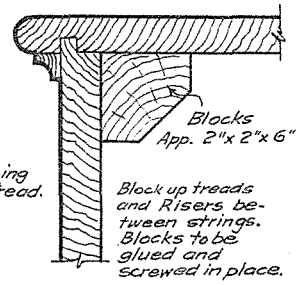
SECTION THRU HANDRAIL



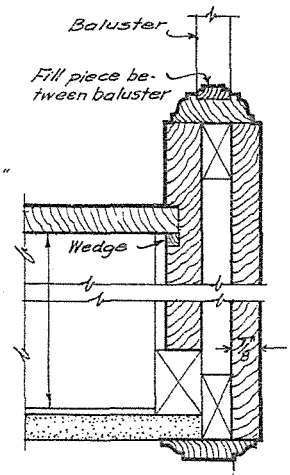
CLOSED STRING STAIR



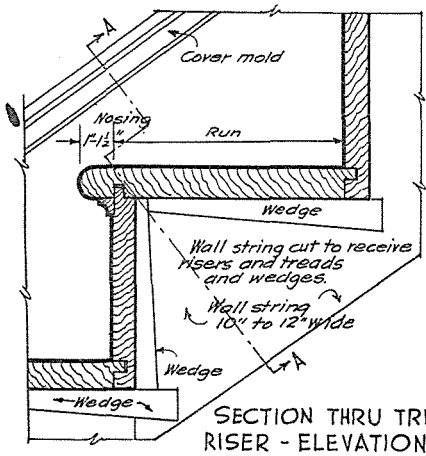
LINE A-A SHOWING SECTION THRU WALL STRING SECTION - CONTINUED ON AND THRU OUTSIDE STRING



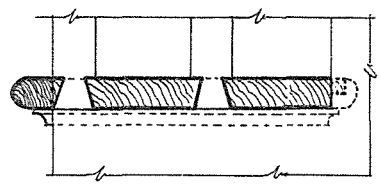
BLOCKING METHOD



CLOSED STRING STAIR SECTION

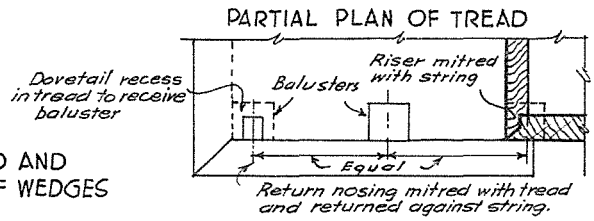


SECTION THRU TREAD AND RISER - ELEVATION OF WEDGES



Tread with return nosing removed to show baluster dovetailed into tread.

PARTIAL PLAN OF TREAD


Dovetail recess in tread to receive baluster
Balusters
Riser mitred with string
Equal
Return nosing mitred with tread and returned against string.

STAIRWAY DETAILS

E. Cabinet Work

Cabinet work differs slightly from the usual run of millwork because the pieces are usually shipped "knocked down" and must be joined together on the job as they are installed. Such items as kitchen cabinets, china closets, bookcases, ironing boards, linen closets and bathroom cabinets are standard and may be furnished in practically any size necessary to fit in a certain space. All wood used in cabinet construction should be properly seasoned and should be as free as possible from defects.

75. Details of Millwork

The production of good millwork calls for close attention to such details as jointing, matching, gluing and sanding. The wood to be used must be properly seasoned and dried before any work is started. This will preclude the possibility of open joints and provide a good appearance in the finished job.

A. Joints

Most of the types of wood joints used in the construction of millwork are illustrated on Page 119 . Joints can be strengthened by the use of hardwood dowel pins, if space is available for their insertion. All wood joints should be glued, and the larger the gluing surface the stronger should be the joint. For this reason, the tongue and groove, dovetail and lock joints are in more common use than any other type.

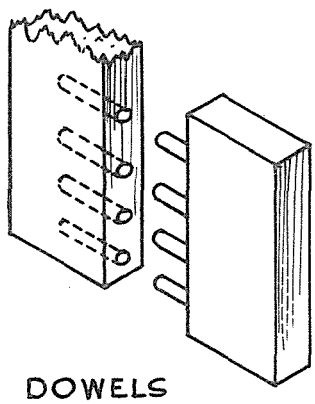
(a) End-Grain Joints

When the end of one board is jointed to the edge of another board, it is practically impossible to make a solid joint connection by the use of glue alone. It is estimated that not more than 25% of the tensile strength of the wood parallel to the grain can be obtained in butt joints. For this reason, some form of mortise and tenon joint or dowel pins should be used.

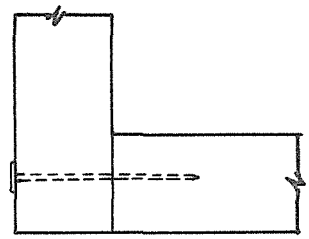
Hardwood, grooved dowel pins should be used in making all joints of this type. The hardwood gives strength and the groove provides for the escape of air and excess glue from the bottom of the dowel pocket.

(b) Side-Grain Joints

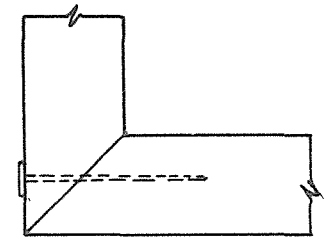
The tongue and groove type of joint is used in practically all cases where the edge of one board is joined to the edge of another board. These joints can be made substantially as strong as the wood itself if proper attention is given to the work. A shallow tongue and groove is usually as satisfactory as a deep cut and wastes much less wood.



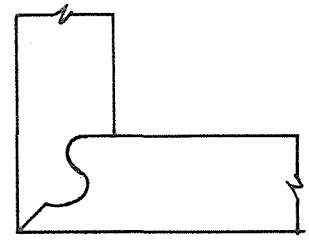
DOWELS



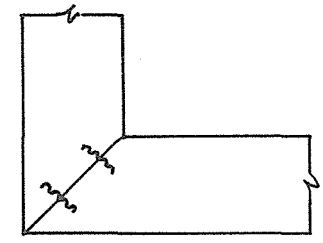
BUTT JOINT



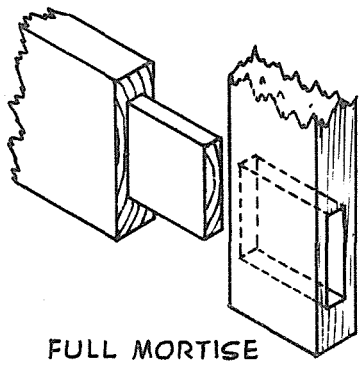
MITRED JOINT



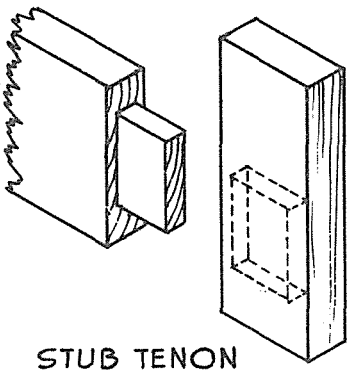
LOCK MITRE JOINT



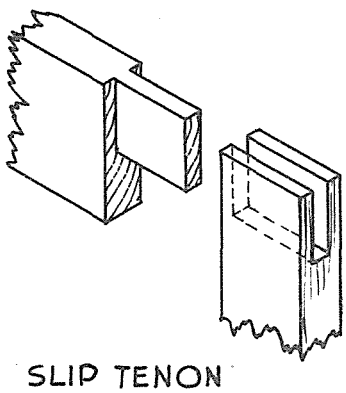
CLEATED MITRE JOINT



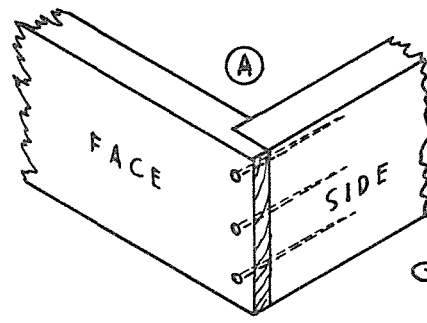
FULL MORTISE AND TENON



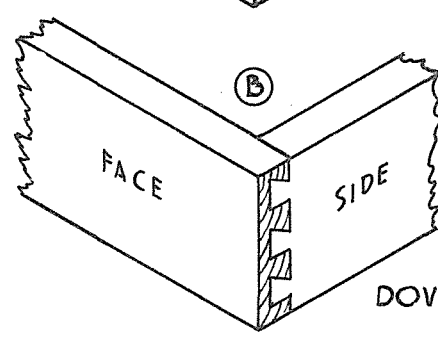
STUB TENON



SLIP TENON



GLUED AND NAILED

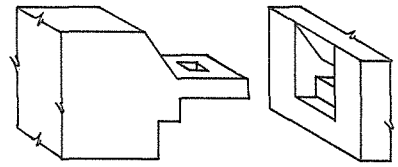


DOVETAILED

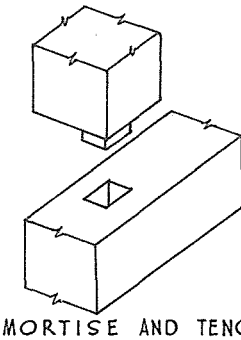
TWO METHODS OF JOINING SIDES AND FACE OF DRAWERS (B) IS BETTER

TONGUE AND GROOVE

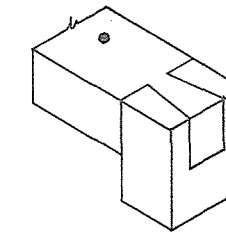
CABINET JOINT DETAILS



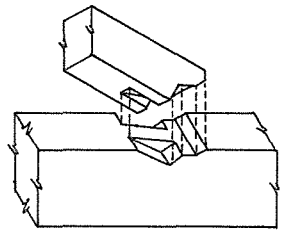
TUSK TENONED JOINT



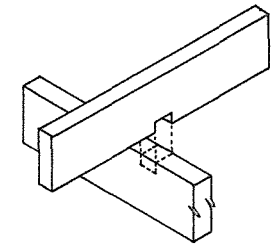
MORTISE AND TENON



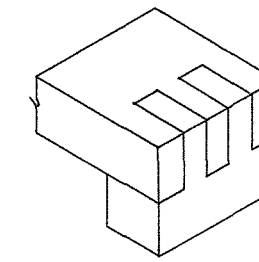
DOVE TAIL



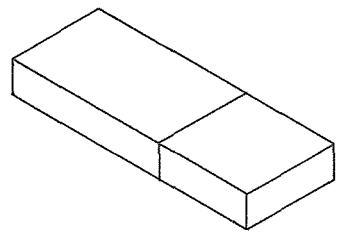
BRIDLE JOINT



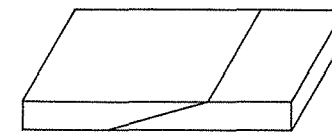
NOTCHING



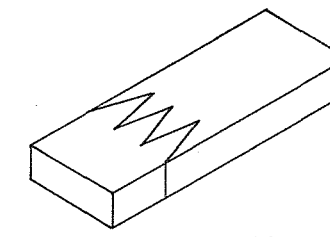
SLIP OR LOCK CORNER



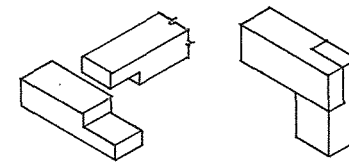
END TO END



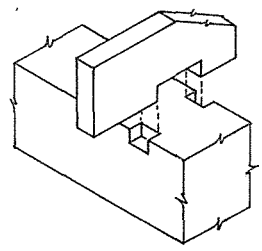
SCARF



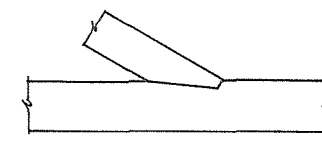
SERRATE OR FINGER



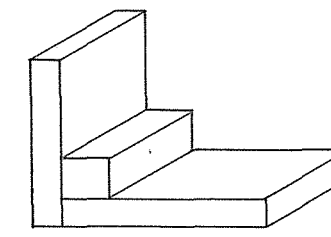
HALVED JOINT



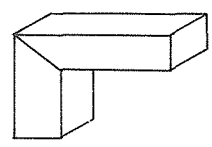
COGGING



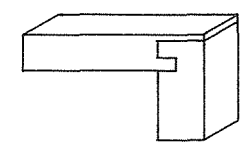
TOE JOINT



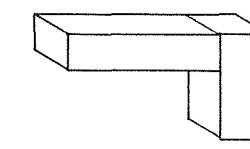
BLOCKED



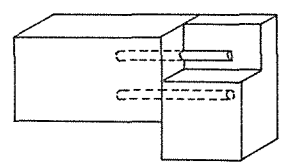
MITRE



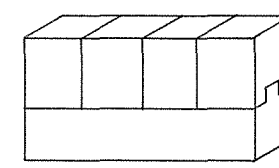
DADO TONGUE AND RABBET



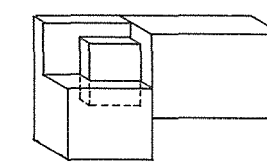
END TO SIDE



DOWEL



TONGUE AND GROOVE



MORTISE AND TENON

JOINT DETAILS

B. Matching

Large wood surfaces are generally built up from smaller boards. They are tongue and grooved and glued together until the correct size is obtained. All materials used in this work should be selected for clear, straight grain to provide for an attractive appearance of the finished product. No set rules are given for this type of work, for each job is a separate problem.

C. Gluing

Gluing is used extensively in the construction of joints and in the manufacture of plywood. It depends, for its efficiency, upon the kind of wood and its preparation for use; the kind and quality of glue and its preparation for use; the details of gluing; the type of joint; the conditioning of the joints, and the protection given in service.

(a) Glues Used in Woodworking

The characteristics, properties, preparation and uses of the three most common types of glue used in making wood joints are described in the Table on Page 121. Animal glues have long been used extensively in woodworking. Starch glues have come into general use in veneer work during the past 25 or 30 years. Vegetable protein and casein glues are of more recent development, but have been used extensively in making water resistant joints.

Other classes of glues are used to some extent in woodworking, but have not come into general use. Most of them have quite different characteristics and properties than the three most common types.

(1) Blood Albumin Glue

Glues made from a base of blood albumin have been used for special purposes for many years but are not used extensively in the United States. The various ingredients are mixed at the time of use and are applied cold. Most of them are quick-setting but require hot pressing. They are high in water resistance and durability under moist conditions. They produce only a slight stain on wood, but their dark colors may show through thin veneer. The principal limitation to their extensive use is the necessity for hot pressing to make them set.

(2) Liquid Glue

Liquid glues, made from vegetable and animal products are sold already prepared for application. Their principal use is for small woodwork jobs and for repair work. They are quite variable in quality although all of them are low in water resistance and

CHARACTERISTICS AND PROPERTIES OF THE MOST COMMONLY USED WOODWORKING GLUES

Class	Grade, form and testing	Properties	Preparation and application	Uses
Animal.....	Many grades sold in dry form; quality most accurately determined by test on solutions of the glue (U. S. Federal Specifications Board).	High to low dry strength; low moisture resistance and durability under damp conditions; set quickly; stain wood not at all or very slightly; moderate dulling effect on tools.	Mixed with water, soaked, and melted; solution kept warm during application; conveniently applied by hand or machine spreaders; pressed cold.	Used extensively in gluing veneer; furniture, cabinet, and millwork.
Casein and vegetable protein.	Several brands sold in dry powder form may also be prepared from raw materials by user; quality judged chiefly by test on wood joints	High to low dry strength high to low moisture resistance and moderately durable under damp conditions; set quickly; stain some woods badly; pronounced dulling effect on tools.	Mixed with cold water and used cold; pressed cold.	Used extensively in gluing lumber and veneer; millwork, plywood, auto bodies and aircraft.
Starch.....	Different grades sold in dry form; quality determined chiefly from joint tests.	High to low dry strength; low in moisture resistance and durability under damp conditions; quick to slow rate of settling; stain some woods slightly to moderately; moderate dulling effect on tools.	Mixed with water usually with heat; applied cold with machine spreaders; pressed cold.	Used extensively in gluing veneer and to some extent in gluing lumber, furniture, and plywood.

durability under moist conditions. The better brands are moderate in dry strength and are fairly quick setting. Liquid glues are applied cold and are pressed cold. They usually produce no stains on wood.

(3) Synthetic Resins

Adhesive cements made from phenolic and other synthetic resins are a recent development in woodwork. They are usually in the form of dry films and aqueous suspensions but may be used as dry powder or non-aqueous solutions. These adhesives usually require the application of heat, but they set quickly. They have good dry strength and are high in water resistance and durability under moist conditions. They seldom produce stains on wood.

(4) Miscellaneous Adhesives

Cellulose cements and rubber compounds which are usually sold in liquid form ready for application to wood have a limited use as woodworking glues. Cellulose cements are pressed cold, but most rubber compounds require heat. Both types produce water resistant joints. The present practical limitation to their extensive use is their high cost.

(b) Glue Stains

Some vegetable protein and casein glues contain chemicals which act on tannin and other constituents of certain kinds of wood to produce stains. Glue stain is not a serious defect unless the wood is to have a natural finish. When too much water is added to glue, the solution penetrates deeply into the wood and produces stains which are very noticeable in thin veneer.

(c) Conditioning Glued Joints

When joints are glued, the wood immediately adjacent to the joint absorbs water and swells more than the rest of the board. If the glued pieces are surfaced before the excess moisture is dried out or has been uniformly distributed, more wood is removed along the joints than at the intermediate points in the board. After the moisture content becomes uniform, greater shrinkage occurs at the joints than elsewhere and permanent depressions are formed. These depressions along the glue line are often very conspicuous in a finished panel.

It is not necessary to completely dry the wood so that the moisture content will be below the average, but sufficient time should be allowed between gluing and finishing for the moisture to be uniformly distributed.

(d) Durability of Glued Members

Most of the common woodworking glues used in making joints are permanently durable under conditions where the wood does not have more than 12% moisture content. Joints made with glues which are not water resistant fail quickly when exposed to moisture. Even the more commonly used water resistant glue joints fail completely after long exposure to free water or high relative humidity or under alternate wet and dry conditions. Special treatments should be given to glued joints when the moisture content of the wood is more than 12%. This increases the serviceability of glued products.

Durability treatments may be grouped into two general classes: (1) coatings that reduce the moisture content changes in the wood and the glue, and (2) impregnation with preservatives or toxic materials. Moisture excluding coatings are useful in reducing the magnitude of moisture content changes and in lessening the weakening effects of swelling stresses, but are not effective against prolonged periods of exposure. The deteriorating effects of prolonged exposure are reduced by impregnation with reliable preservatives such as coal-tar creosote or a 10% solution of beta-naphthol in a volatile solvent.

D. Sanding

Woodwork is sanded to provide a good base for the finish which is to be given to it and to bring it down to the correct dimensions. Sanding may be done by the use of machines or by hand. Care should be used in the selection of the sandpaper. The coarser grades cut faster while the finer grades provide a fine polish.

76. Preliminary Work before Placing Millwork

The framework of buildings must be prepared to receive the interior trim. This preparation usually consists of the addition of ground strips to provide nailing surfaces for the trim and to establish the thickness of the plaster. The thickness and width of ground strips may vary with conditions, but the average size is 3/4" x 1-½". All openings must be provided with grounds to which the frames are nailed. Furring pieces must be provided for wall extensions.

77. Finish and Painting

The subject of painting and finishing woodwork is covered in Chapter XXV. There are a few points to be kept in mind regarding the protection of millwork. All lumber to be used on the inside of a building should be treated with a preliminary preservative coat when it is received on the job. It is especially necessary that trim work be treated on the back as well as on the face. Doors, door frames, windows and window frames should be given a priming coat to protect them against changes in humidity. Bulletins on the raw materials from which paint is produced may be obtained from the Institute of Paint and Varnish Research, Washington, D. C.

78. Hardware

The subject of hardware is discussed in Chapter XXIV. All pieces of hardware entering into a building should be properly protected during construction. They should be removed during the time of painting and finishing to prevent discoloration and damage due to dropping paint.

79. General Inspection

The final appearance of the finished millwork in a building depends entirely upon the attention that has been given to it during the time of construction. Each detail should be carefully observed. No material should be accepted on the job unless the specifications are fully met. The building plans should be carefully followed so that the finished product will conform to the ideas of the designer. The work should be done systematically. No parts should be installed before all preparatory measures have been taken to provide a good job.

Reference:

Wood Handbook - U. S. Forest Products Laboratory.

80. Types of Construction

The three common types of wood framing are known as balloon framing, braced framing and western framing. The main difference between the three is the method of fastening the studs. It is difficult to draw distinct lines between these three types as they are modified in actual practice. Each type has its advantages, and each affords satisfactory results. They are framed in accordance with the illustrations shown on Pages 126, 127 and 128.

A. Balloon Framing

Most builders use the balloon type of framing because of its economy and ease of construction. Its main feature is that the supporting studs extend from the lower foundation wall to the eaves. The resulting building is not as rigid as when other types of construction are used unless the sheathing is placed diagonally. Bracing is accomplished by notching the studs a sufficient depth to set in the diagonal braces. In this type of construction floor headers and fire strips are omitted. These omissions permit heat losses by too free circulation of air, and are a constant fire menace. One advantage of continuous studs is that cracks are less likely to occur in stucco finish.

B. Braced Framing

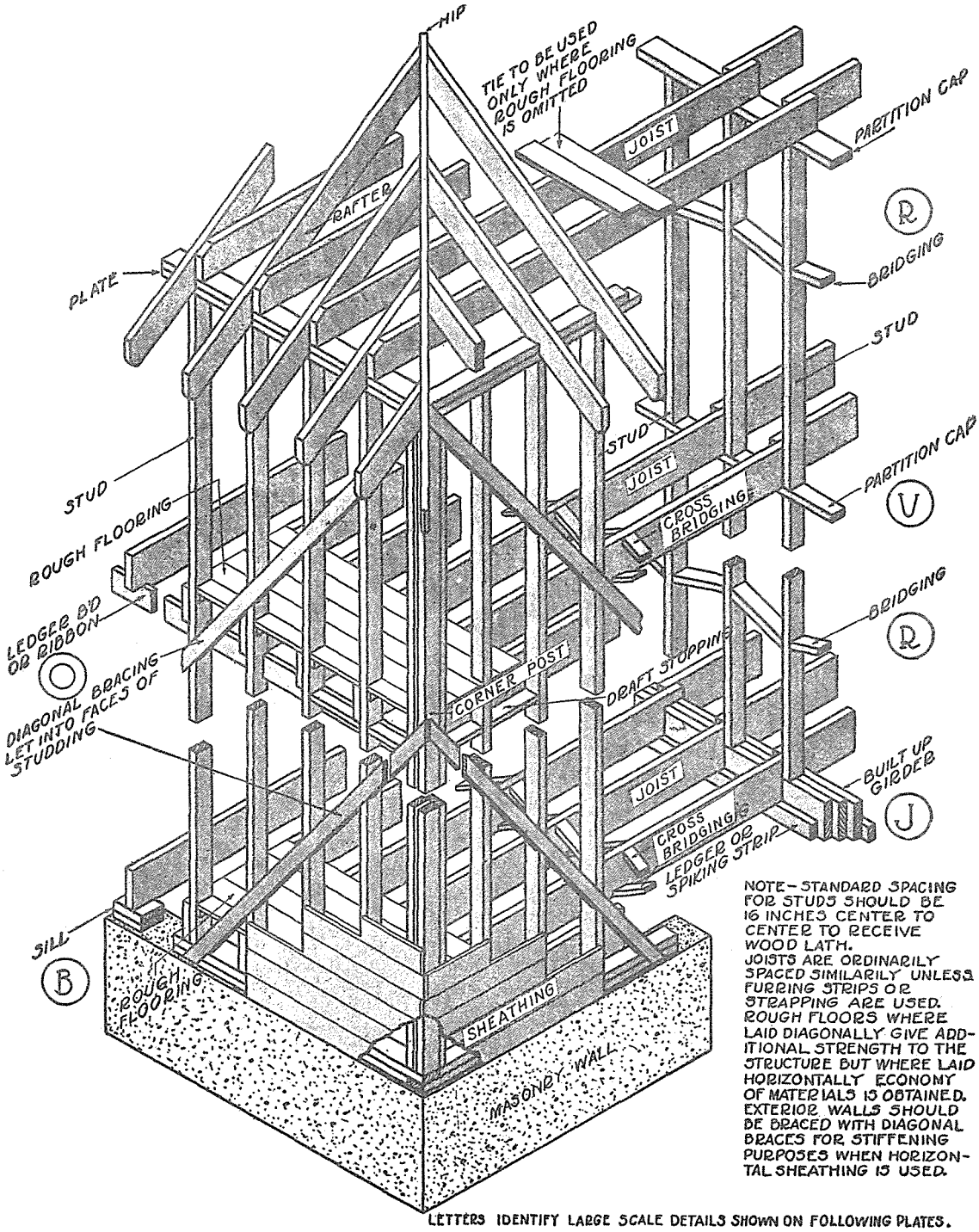
The main difference between this type of framing and that described above is that the supporting studs are framed separately for each story of the building. Solid corner posts extend from the foundation to the eaves. The joists are supported on heavy girts framed into the posts, and the studs are cut in between the girts. This type of construction is strongly braced at each corner on each floor level by the use of 2" x 4" strips. This gives rigidity, strength and durability.

C. Western Framing

This type of framing has very limited use and is not recommended. Its main feature is that the studs extend from the top of one tier of posts to the lower side of the next tier above. Each set of studs is provided with a top plate and a bottom plate. The original idea was to overcome the effects of unequal shrinkage. The result is a framework of flimsy construction.

81. Plans and Specifications

Plans for frame buildings should contain sufficient information so that they can be followed by anyone. Specifications should cover all details of construction. Any special details mentioned in

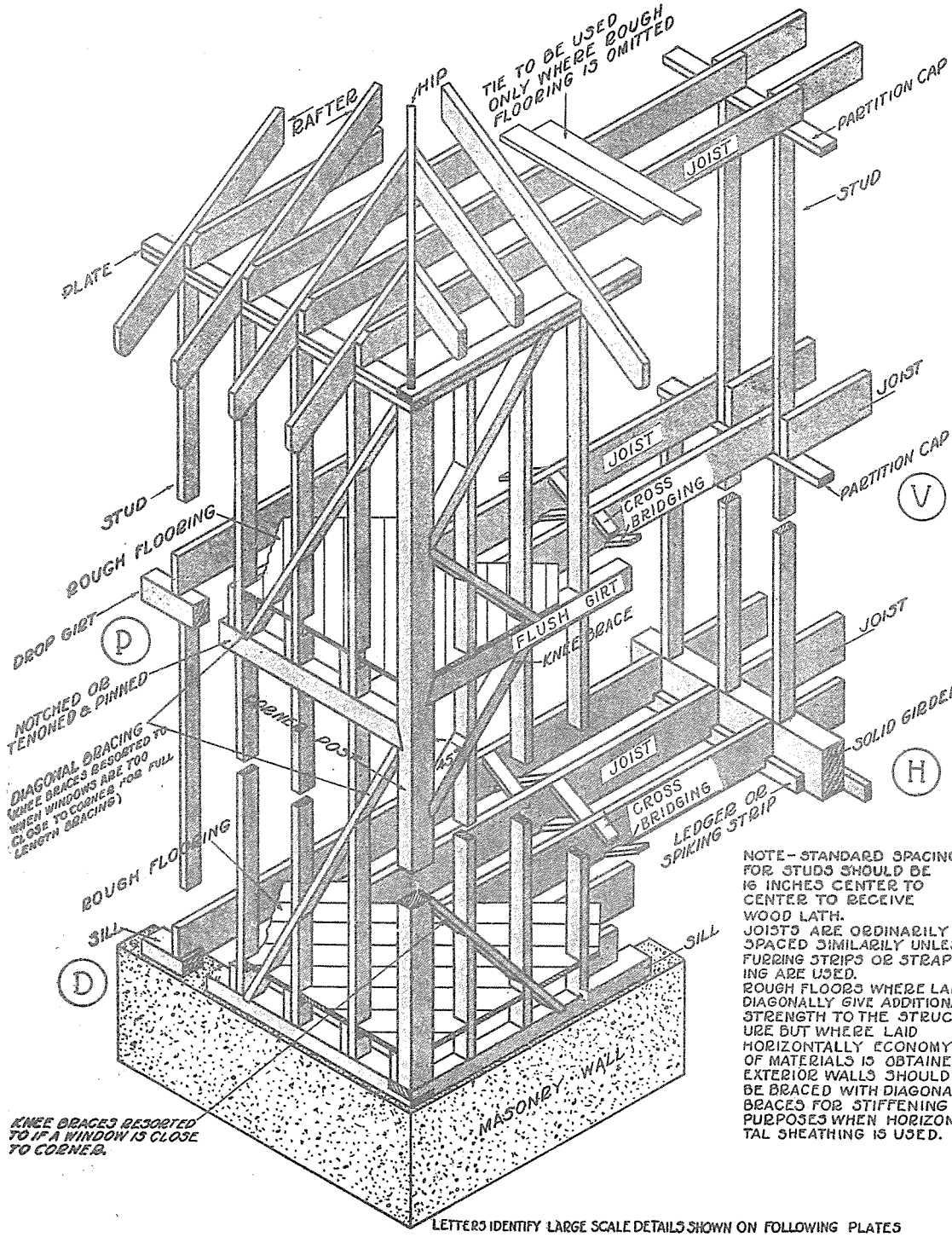


NOTE – STANDARD SPACING FOR STUDS SHOULD BE 16 INCHES CENTER TO CENTER TO RECEIVE WOOD LATH. JOISTS ARE ORDINARILY SPACED SIMILARILY UNLESS FURRING STRIPS OR STRAPPING ARE USED. ROUGH FLOORS WHERE LAID DIAGONALLY GIVE ADDITIONAL STRENGTH TO THE STRUCTURE BUT WHERE LAID HORIZONTALLY ECONOMY OF MATERIALS IS OBTAINED. EXTERIOR WALLS SHOULD BE BRACED WITH DIAGONAL BRACES FOR STIFFENING PURPOSES WHEN HORIZONTAL SHEATHING IS USED.

LETTERS IDENTIFY LARGE SCALE DETAILS SHOWN ON FOLLOWING PLATES.

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

BALLOON FRAME CONSTRUCTION

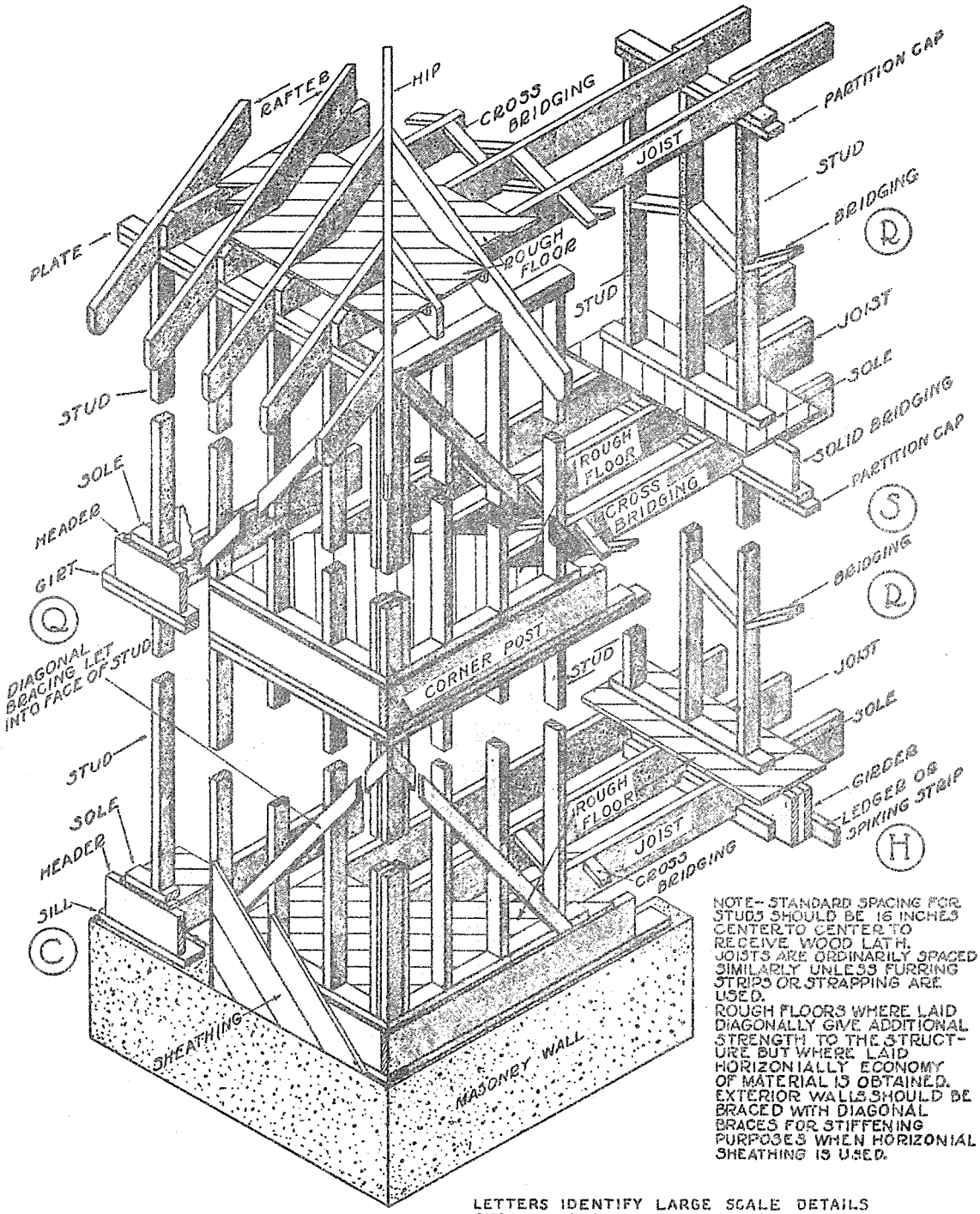


NOTE – STANDARD SPACING FOR STUDS SHOULD BE 16 INCHES CENTER TO CENTER TO RECEIVE WOOD LATH.
JOISTS ARE ORDINARILY SPACED SIMILARILY UNLESS FURRING STRIPS OR STRAPPING ARE USED.
ROUGH FLOORS WHERE LAID DIAGONALLY GIVE ADDITIONAL STRENGTH TO THE STRUCTURE BUT WHERE LAID HORIZONTALLY ECONOMY OF MATERIALS IS OBTAINED.
EXTERIOR WALLS SHOULD BE BRACED WITH DIAGONAL BRACES FOR STIFFENING PURPOSES WHEN HORIZONTAL SHEATHING IS USED.

LETTERS IDENTIFY LARGE SCALE DETAILS SHOWN ON FOLLOWING PLATES

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

BRACED FRAME CONSTRUCTION



NOTE- STANDARD SPACING FOR STUDS SHOULD BE 16 INCHES CENTER TO CENTER TO RECEIVE WOOD LATH. JOISTS ARE ORDINARILY SPACED SIMILARLY UNLESS FURRING STRIPS OR STRAPPING ARE USED.
ROUGH FLOORS WHERE LAID DIAGONALLY GIVE ADDITIONAL STRENGTH TO THE STRUCTURE BUT WHERE LAID HORIZONTALLY ECONOMY OF MATERIAL IS OBTAINED. EXTERIOR WALLS SHOULD BE BRACED WITH DIAGONAL BRACES FOR STIFFENING PURPOSES WHEN HORIZONTAL SHEATHING IS USED.

LETTERS IDENTIFY LARGE SCALE DETAILS SHOWN ON FOLLOWING PLATES

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

WESTERN FRAME CONSTRUCTION

in the specifications should be supplemented by detailed drawings.

82. Choice of Wood

The choice of wood to be used in building construction is very important. A detailed discussion of the selection and use of different kinds of wood is given in Chapter VIII.

83. Light Framing

Load supporting members are seldom stressed to their full capacity in light building construction. Joists should be strong enough and rigid enough to withstand all ordinary live loads brought on them.

Early construction called for the use of elaborate joints such as mortise and tenon. Such joints are seldom used in construction at the present time because of the high labor cost. Practically all connections are now made by the use of nails.

The economical use of wood involves both strength and stiffness. The strength of a timber varies as its width and as the square of its depth. The stiffness which it offers to flexure varies as the cube of its depth.

It is often possible to use a cheaper grade of material by increasing the depth of a timber. Standard mill sizes should be used wherever possible.

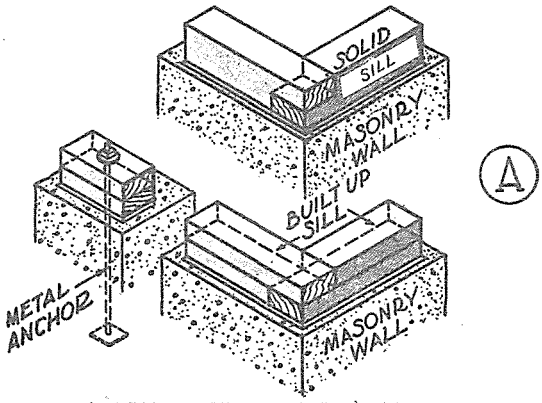
The Wood Handbook prepared by the Forest Products Laboratory contains valuable information on wood used for structural purposes. The National Lumber Manufacturers Association of Washington, D. C. has prepared a number of publications which give design data for framing.

84. Sills

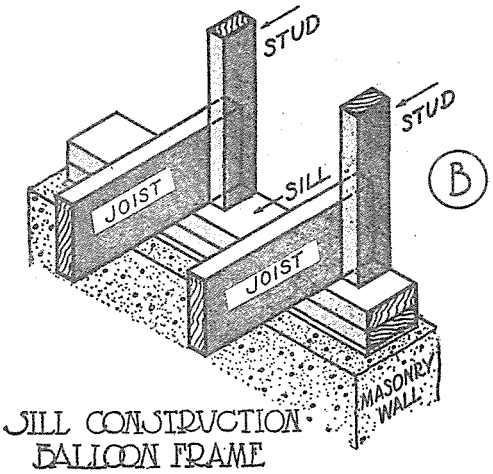
Sills should be run continuously from corner to corner of the building. They should never be butted together or mitred, but should be halved and spiked. Sills should be laid in mortar to provide an air-tight joint between them and the foundation. They should be anchored to the foundation by bolts placed not over 6 feet apart. Anchor bolts should extend into the foundation wall at least 18 inches. Sills should be thoroughly treated with asphalt before being placed in the mortar. Cedar sills do not require this treatment. Box sills are not as satisfactory as solid sills.

Sills should be set back at least 1 inch from the outside line of the masonry to make room for the sheathing. Sills should be protected against contact with soil to prevent deterioration.

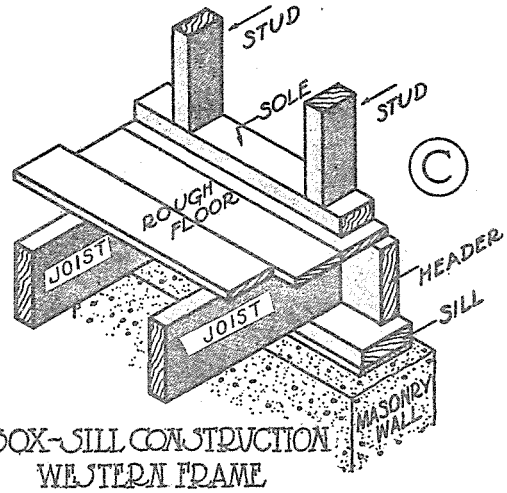
ALL SILLS SHOULD BE BEDDED IN MORTAR AND SECURELY ANCHORED TO MASONRY



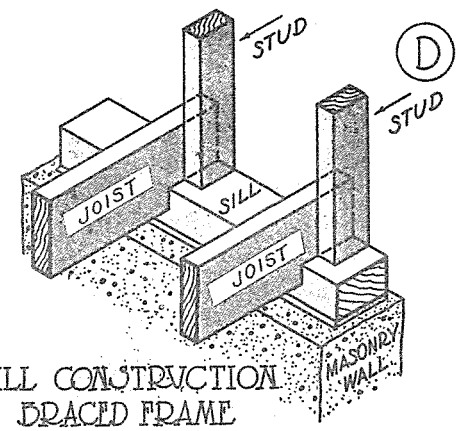
HALVING OF SILLS AT CORNER



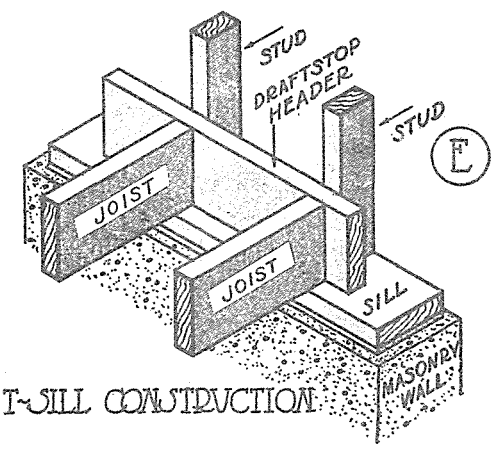
SILL CONSTRUCTION
BALLOON FRAME



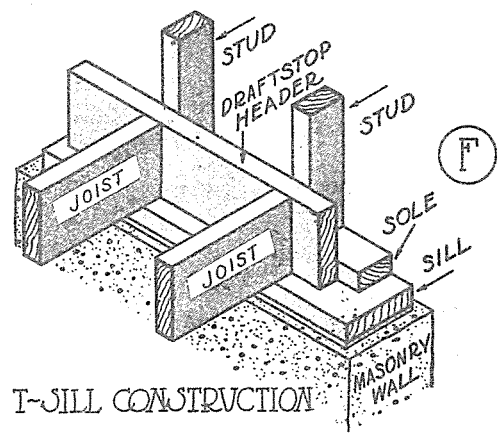
BOX-SILL CONSTRUCTION
WESTERN FRAME



SILL CONSTRUCTION
BRACED FRAME



T-SILL CONSTRUCTION



T-SILL CONSTRUCTION

BY COURTESY OF
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JOIST AND SILL DETAILS

85. Basement Posts.

Concrete or masonry foundations should be provided for all upright posts which are used to support girders or beams. The ends of the posts should be thoroughly treated with asphalt before the posts are set. It is good practice to raise the top of the footings at least 3 inches above the basement floor. This will help to prevent the posts from coming in contact with water which might accumulate on the floor.

86. Joists.

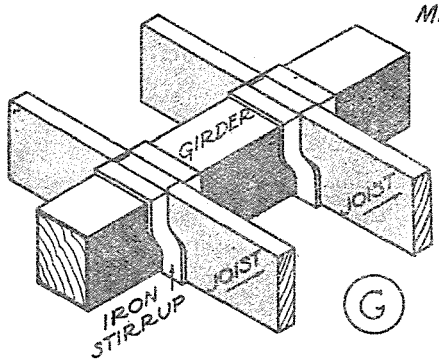
Joists are usually placed on 16 inch centers to match the stud spacing. In some cases the spacing may be 12 inches or 24 inches, depending upon the weight which is to be placed upon the floor. The usual length joist is not more than 16 feet. Joists should be braced with cross-bridging at intervals not exceeding 8 feet. A careful check should be made to see that the tops of all of the joists are on a level before the sub-floor is laid upon them. Joists may be levelled by dapping on the lower side where they rest on the sills.

Joists which rest on masonry or concrete walls should have a bearing of at least 3 inches, or should be supported by suitable metal hangers. Joists which run parallel with masonry walls should be anchored to the walls at at least one place between the end bearings. Joists which carry partitions running in the same direction, and all joists around stairwells, should be made double width.

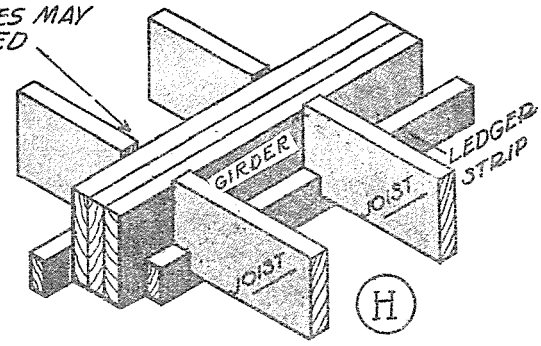
Joists should be supported directly on the sills or girders and should be spiked to the supporting studs. If this method is impracticable, the joists may be framed to the sill or girders by the use of ledger strips or iron stirrups. The ledger strips should be fastened to the sill or girder by the use of through bolts. If stirrups are used, they are supported over the top of the sill and fastened securely.

Joists should be set so that their tops will be 1/4 inch above the top of the cross girders in order to avoid the possibility of their settling below the level of the girders. Joists can be framed into I-beam girders by the use of steel stirrups or by the use of blocks which rest on the bottom flange of the beam and are bolted to it to act as a support. Side joists should be placed directly over the sills to provide fire stops between the studs and to serve as a nailing surface for the flooring.

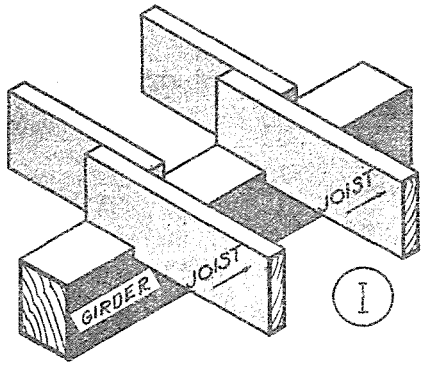
The size and spacing of joists for Forest Service buildings should generally be taken from tables made available by the Forest Products Laboratory. The instructions given on the tables should be carefully followed. If spans are limited by horizontal shear and by bearing stress, they should be checked against each other for the particular loading involved and the shorter span should be used. When designing for stiffness, it is necessary to check the span lengths for deflection, bending and shear, and to use the shortest span of the three given.



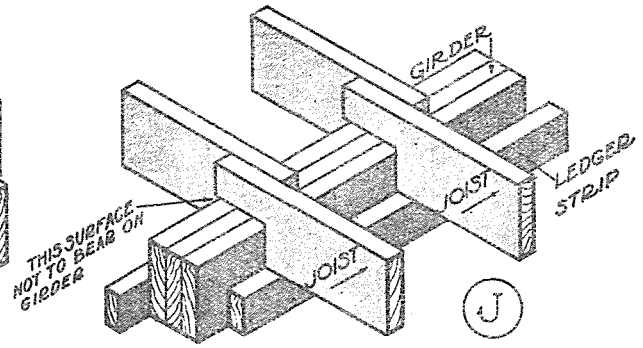
JOISTS HUNG ON GIRDER WITH IRON STIRRUPS



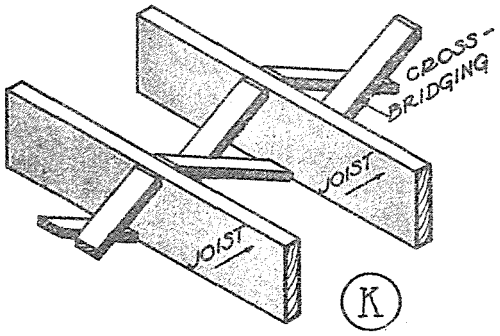
GIRDER CONSTRUCTION TO EQUALIZE SHRINKAGE BRACED & WESTERN FRAME



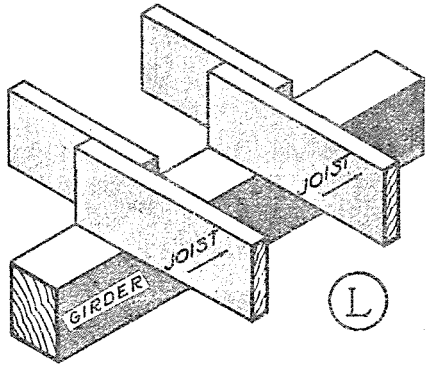
JOISTS SIZED DOWN 1 IN. ON GIRDER WITH LAP



GIRDER CONSTRUCTION TO EQUALIZE SHRINKAGE BALLOON FRAME



CROSS-BRIDGING BETWEEN JOISTS



JOISTS LAPPED ON TOP OF GIRDER

DIMINISHED DEPTH OF BEAM AT BEARING POINTS REDUCES CARRYING CAPACITY.

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

JOIST AND GIRDER DETAILS

87. Building Framework

The most important items in the framework of a building consist of the sills, studs, corner posts, plates and bracing. As stated previously, sills should preferably be of solid material although built up members are often used. Studs should never be built of smaller material than 2" x 4". Many recent plans call for the studding to be of 2" x 6" lumber to make plumbing installations easier and to conceal soil pipes. The usual stud spacing is 16 inches center to center.

Corner posts should rest on top of the sills and should be spiked to them. They should preferably be of solid material and should never be less than 4" x 4". In some cases the minimum requirement is a post 4" x 6". The use of plates is dependent upon the type of framing used. In all cases plates must be placed on top of the studs to support the rafters. They should be at least the same size as the stud material.

Proper bracing of a frame building is of the utmost importance. If buildings are not to receive a stucco finish, bracing may be accomplished by the use of diagonal sheathing. In other cases bracing may be accomplished by the use of diagonal bracing set in to the studs or by the use of bridging set between the studs.

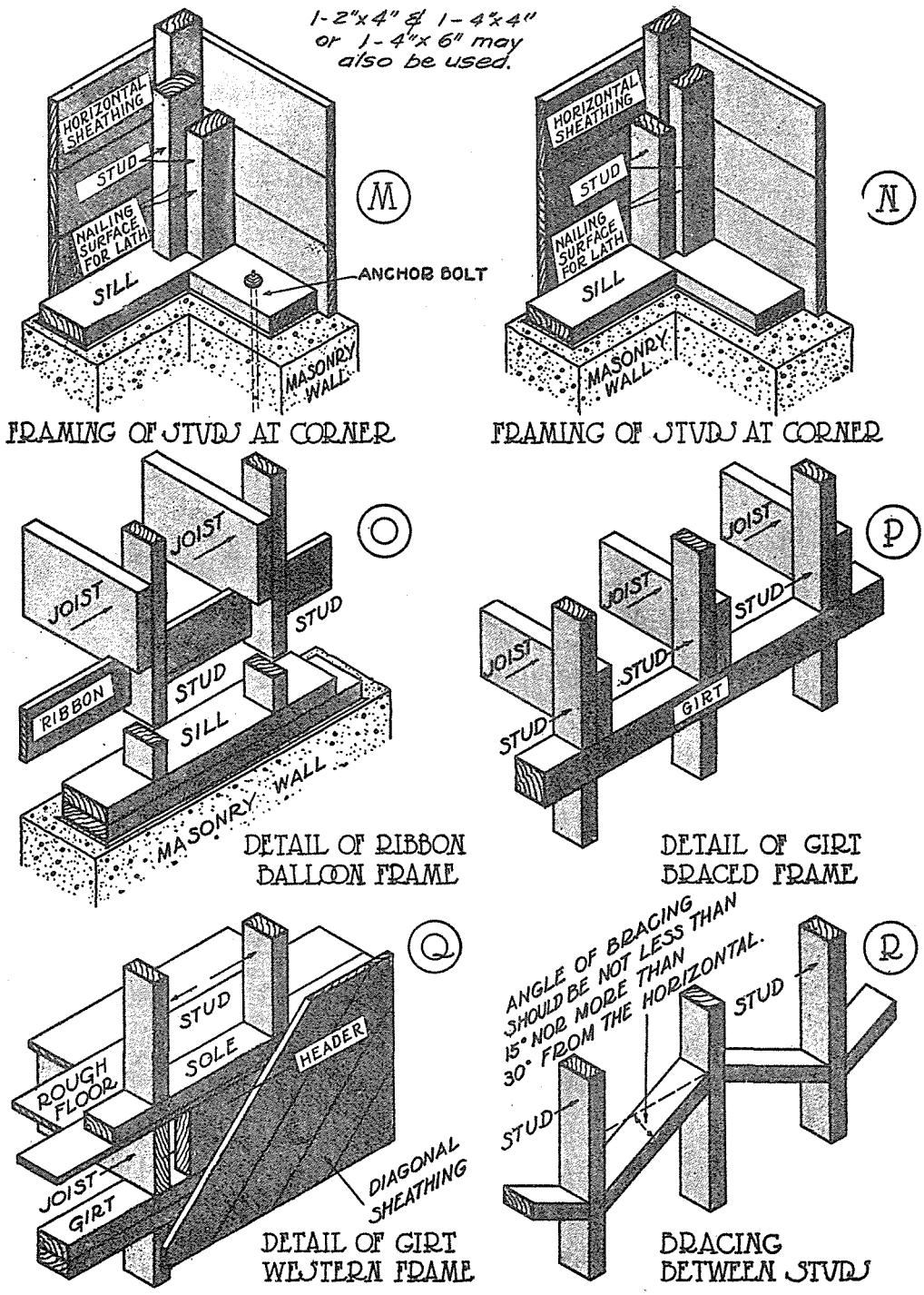
Another item of importance in framing is that the building be tied together to withstand the thrust of the rafters. If it is not feasible to make the ties at the foot of the rafters, the thrust must be transferred to the end walls by a system of diagonal bracing on the under side of the rafters.

88. Framing Around Openings

Double studding should be placed at the sides of all openings. The top header should be installed as a cap over the inside studs to give solid support for the studs directly over the opening. Wider openings require diagonal bracing or trussing to give the required strength. Good practice requires that a 1 inch space be left at the head of an opening so that the sag which develops because of weight above will not be transmitted to the lower head piece and cause binding of the doors or windows. Headers on large openings should be set with the larger dimension vertical. Framing is illustrated on Page 138.

89. Window Construction

The three essential parts of a window are the frame, the sash and the inside finish. Each part is described separately in the specifications and detailed drawings of each part are shown in the plans. The method of installing window frames is essentially the same for wood, masonry or brick buildings. A discussion of the various parts of a window is given in Chapter IX.



BY COURTESY OF
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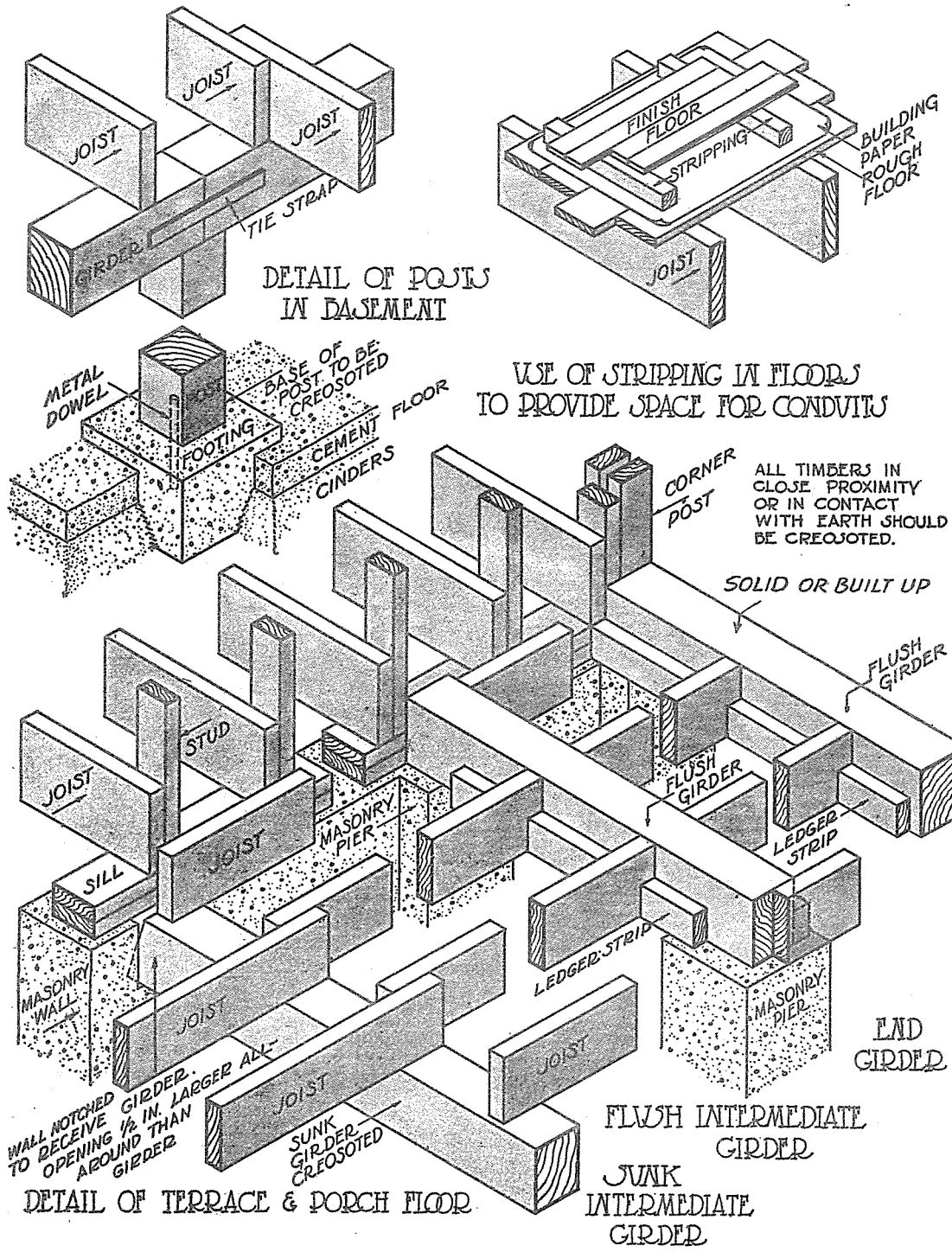
CORNER AND STUD DETAILS



BY COURTESY OF
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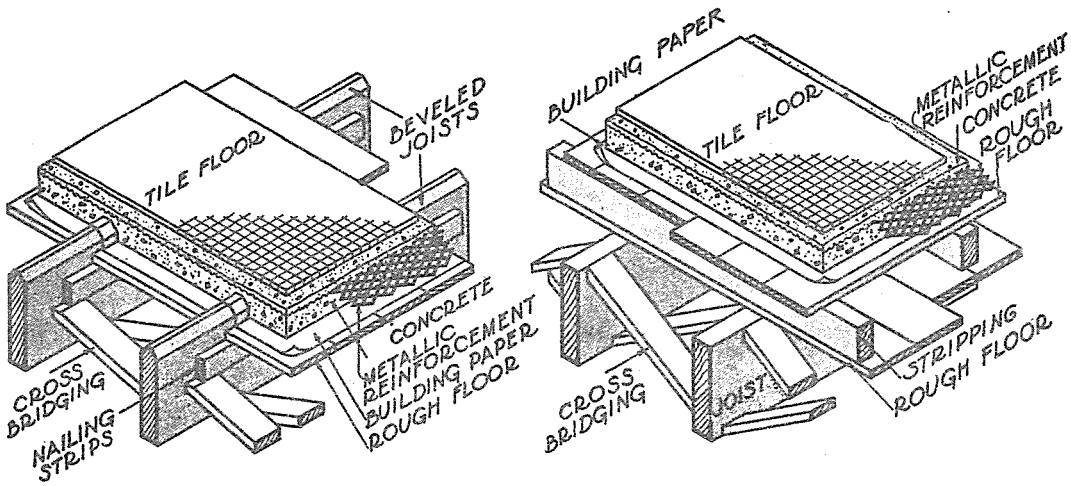
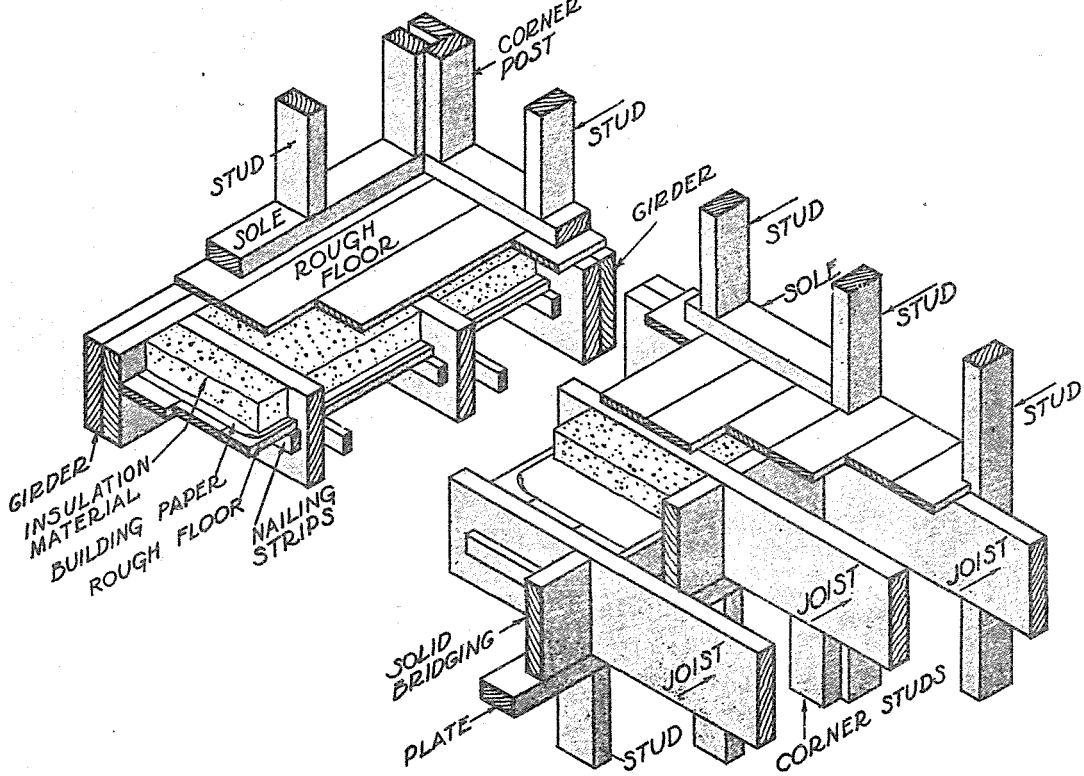
FRAMING DETAILS



TILE FLOOR FLUSH WITH MAIN FLOOR TILE FLOOR STEPPED UP

METHODS OF LAYING TILE FLOORS



DETAIL OF SECOND FLOOR OVER THE REAR PORCH

BY COURTESY OF
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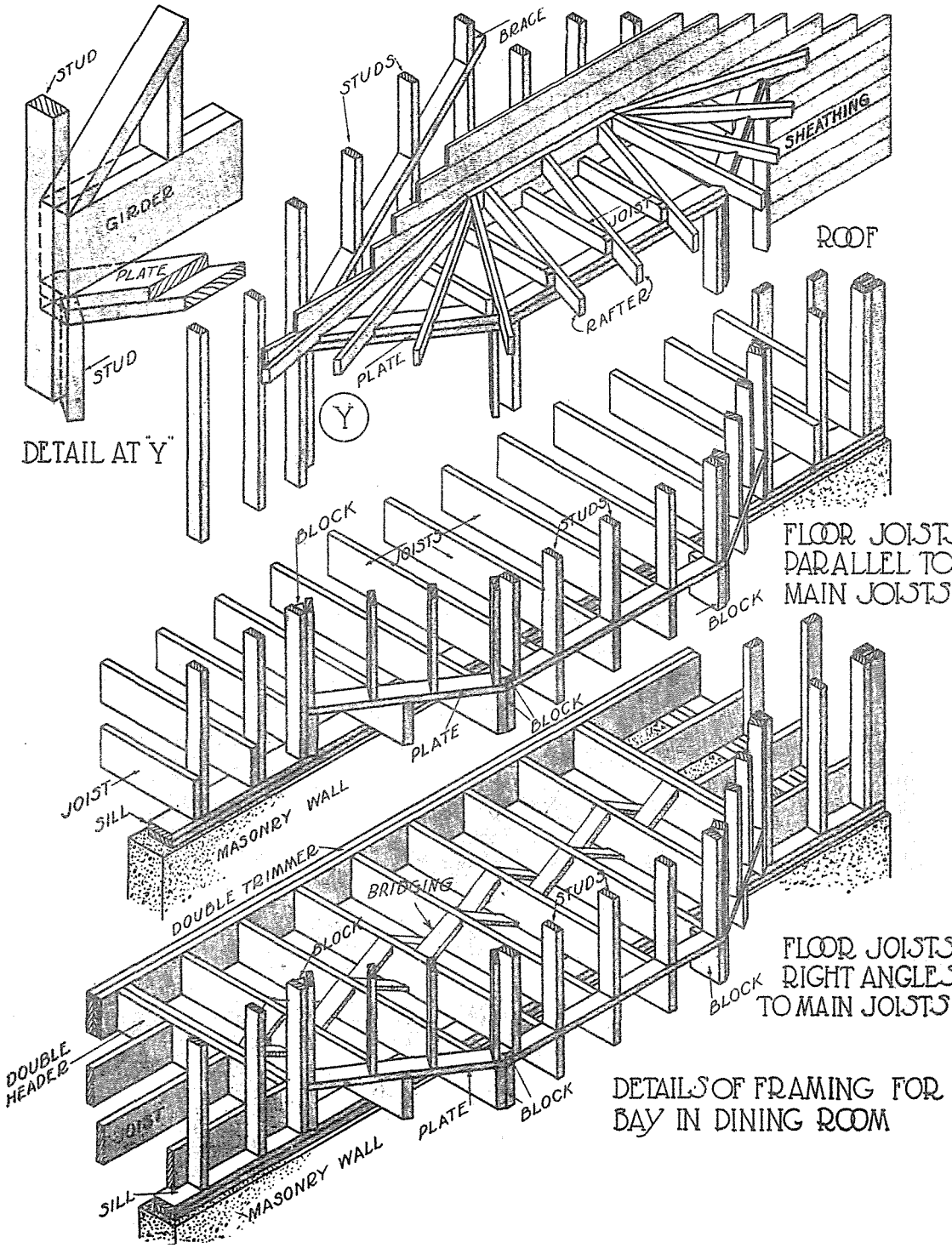
FRAMING DETAILS



BY COURTESY OF
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FRAMING DETAILS

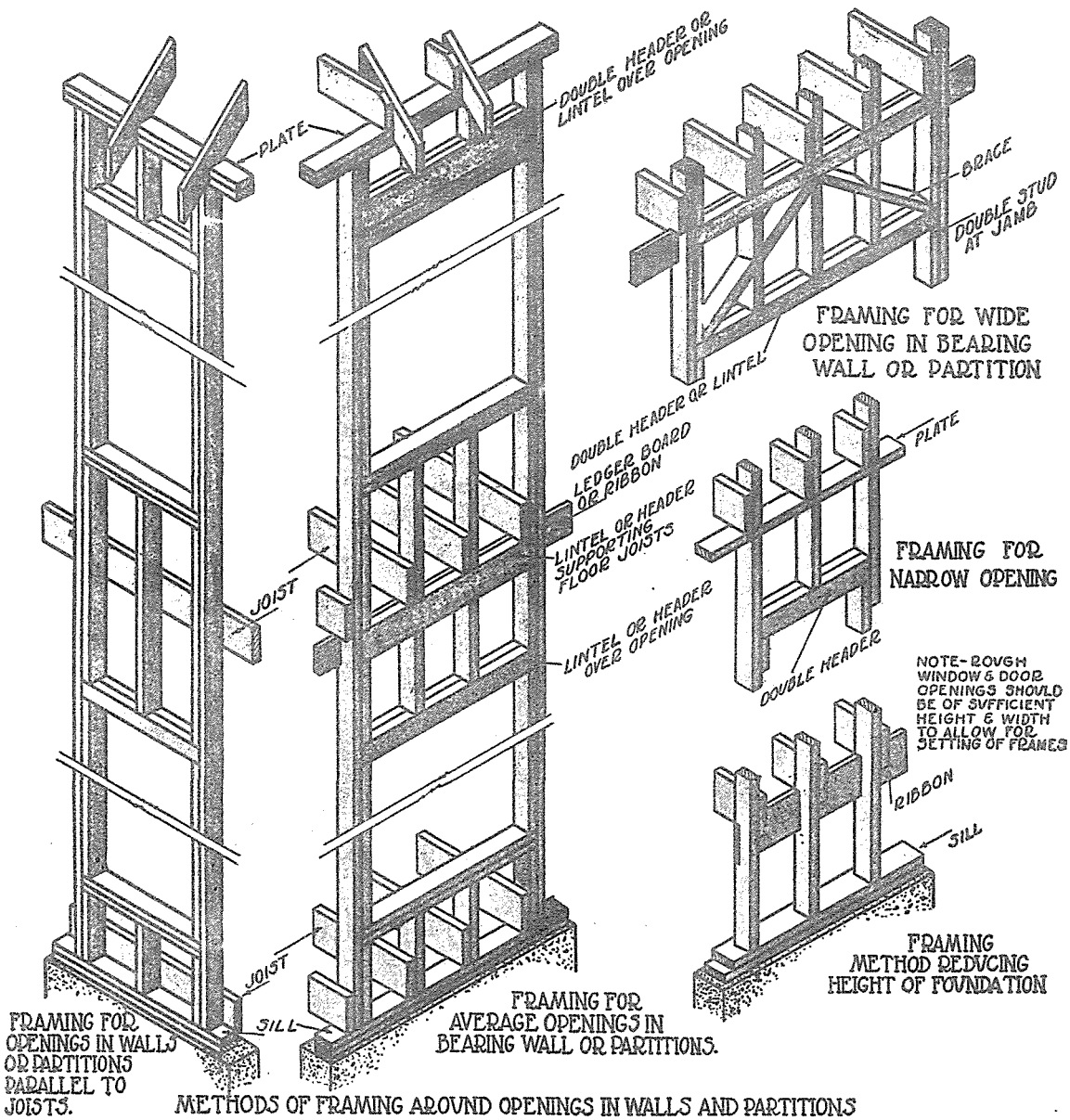
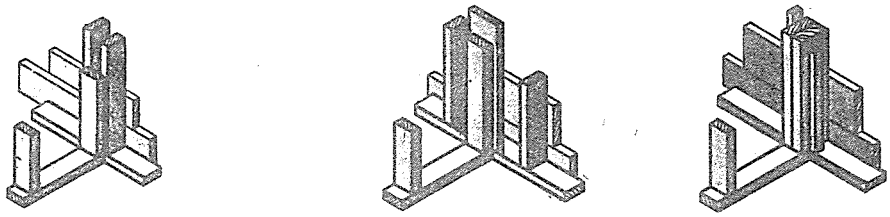


PLATE
DOUBLE HEADER OR LINTEL OVER OPENING
BRACE
DOUBLE STUD AT JAMB
DOUBLE HEADER OR LINTEL
FRAMING FOR WIDE OPENING IN BEARING WALL OR PARTITION
DOUBLE HEADER
LEDGER BOARD OR RIBBON
LINTEL OR HEADER SUPPORTING FLOOR JOISTS
LINTEL OR HEADER OVER OPENING
JOIST
PLATE
FRAMING FOR NARROW OPENING
NOTE- ROUGH WINDOW & DOOR OPENINGS SHOULD BE OF SUFFICIENT HEIGHT & WIDTH TO ALLOW FOR SETTING OF FRAMES
RIBBON
SILL
FRAMING METHOD REDUCING HEIGHT OF FOUNDATION
JOIST
SILL
FRAMING FOR OPENINGS IN WALLS OR PARTITIONS PARALLEL TO JOISTS.
FRAMING FOR AVERAGE OPENINGS IN BEARING WALL OR PARTITIONS.

METHODS OF FRAMING AROUND OPENINGS IN WALLS AND PARTITIONS



METHODS OF FRAMING STUDS AT PARTITION CORNERS

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

FRAMING DETAILS

All joints around window openings should be sealed to prevent the entrance of air and water. Weather strips have been developed which materially assist in this part of construction. The joint between the drip caps and the bracket molding should be made water-tight by the use of metal flashing.

The outside parts of a window frame which are exposed to the weather should be made of such weather resistant species as Southern pine, Ponderosa pine, Sugar pine, Douglas fir, Western red cedar, cypress and redwood. Pulley stiles on the inside of the frames should be made of Southern pine or Douglas fir because of their resistance to hard wear. They should be preserved by oiling or staining. Reference to Chapter VIII will aid in the selection of the materials to be used.

90. Door Construction

The construction of door frames is slightly different in frame buildings than it is in masonry or brick buildings. In wood buildings the door frames are made secure by the use of blocks placed between the studding and the door jamb. In masonry buildings the frames are secured by fastening to nailing blocks which have been previously set in the masonry. Door bucks are made secure in tile partitions by the use of metal anchors.

Door frames should be placed so that the inside edge of the frame will set flush with the finished plaster. The joint between the plaster and the frame can then be covered with the door casing.

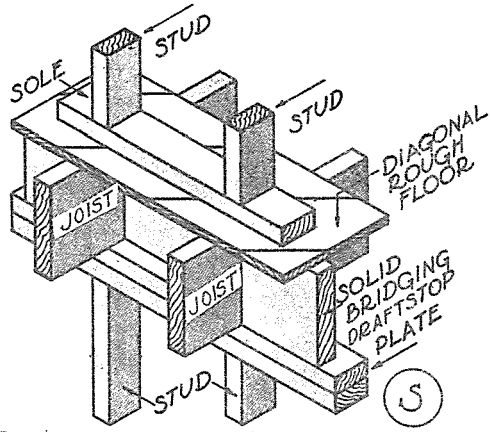
91. Porches

Porch floors are usually supported by masonry or concrete piers, with the space between the piers enclosed by lattice work. In some localities wooden posts of the more durable species give satisfaction as supports. Adequate ventilation must be provided when a solid foundation encloses the space under the wood floor.

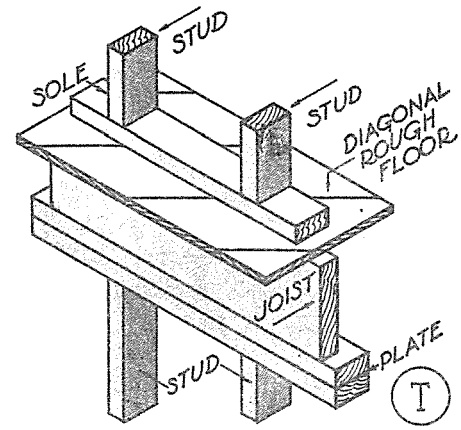
Porch flooring should run perpendicular to the wall of the house and should be pitched to allow water to drain off quickly. The pitch should be at least 1 inch in 6 feet. Where tongue-and-groove flooring is used, the edges of each board should be painted with white lead and oil or should be set in white lead to make the joints water-tight. Concrete or masonry floors are more generally desirable.

92. Partitions

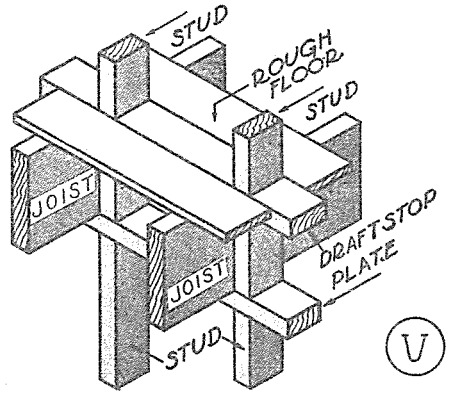
The partition studding of ordinary single story buildings is usually of 2" x 4" material spaced on 16 inch centers. For bearing partitions, and where the height exceeds 9' 6", a stud spacing of 12 inches may be desirable. A stud spacing of 12 inches makes a stiffer job of plastering, and is to be preferred in the better class of dwellings. When partitions exceed 11 feet in height, 2" x 6" studding should be used. The 6 inch studding provides more room for pipes and is often used for this reason.



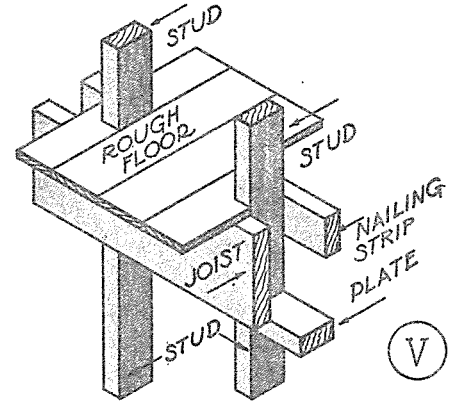
PARTITION AT RIGHT ANGLES TO JOISTS
WESTERN FRAME



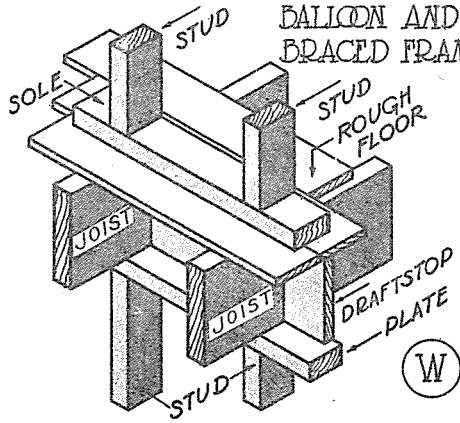
PARTITION PARALLEL WITH JOISTS
WESTERN FRAME



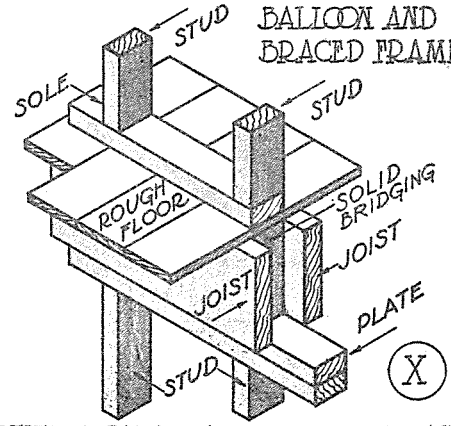
PARTITION AT RIGHT ANGLES TO JOISTS
BALLOON AND BRACED FRAME



PARTITION PARALLEL WITH JOISTS
BALLOON AND BRACED FRAME



PARTITION AT RIGHT ANGLES TO JOISTS
BALLOON FRAME



PARTITION PARALLEL WITH JOISTS AND
JOISTS SPREAD FOR PIPES ETC

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

PARTITION DETAILS

Partitions must be built so there will be little settling due to shrinkage. This is especially true of bearing partitions which act to support the joists in the second and third stories. Interior partitions must be bridged to provide stiffness. Details of partition framing are shown on Page 140.

It is sometimes necessary to run a partition parallel to the joists and of such a length that sagging might be expected. The tendency to sag should be overcome by trussing the partition. Trusses must have ample bearing and support and should be slightly crowned. Trussing will not prevent settlement from shrinkage unless the bottom member of the truss is thoroughly seasoned.

93. Lath and Wallboard

Lath serves as a base on which plaster is applied. It may be of wood or metal. The standard size of wood lath is 3/8" x 1½" x 4" long. Laths must be straight grained, thoroughly seasoned and free from knots. They are laid horizontally and must be spaced not less than 3/8" apart.

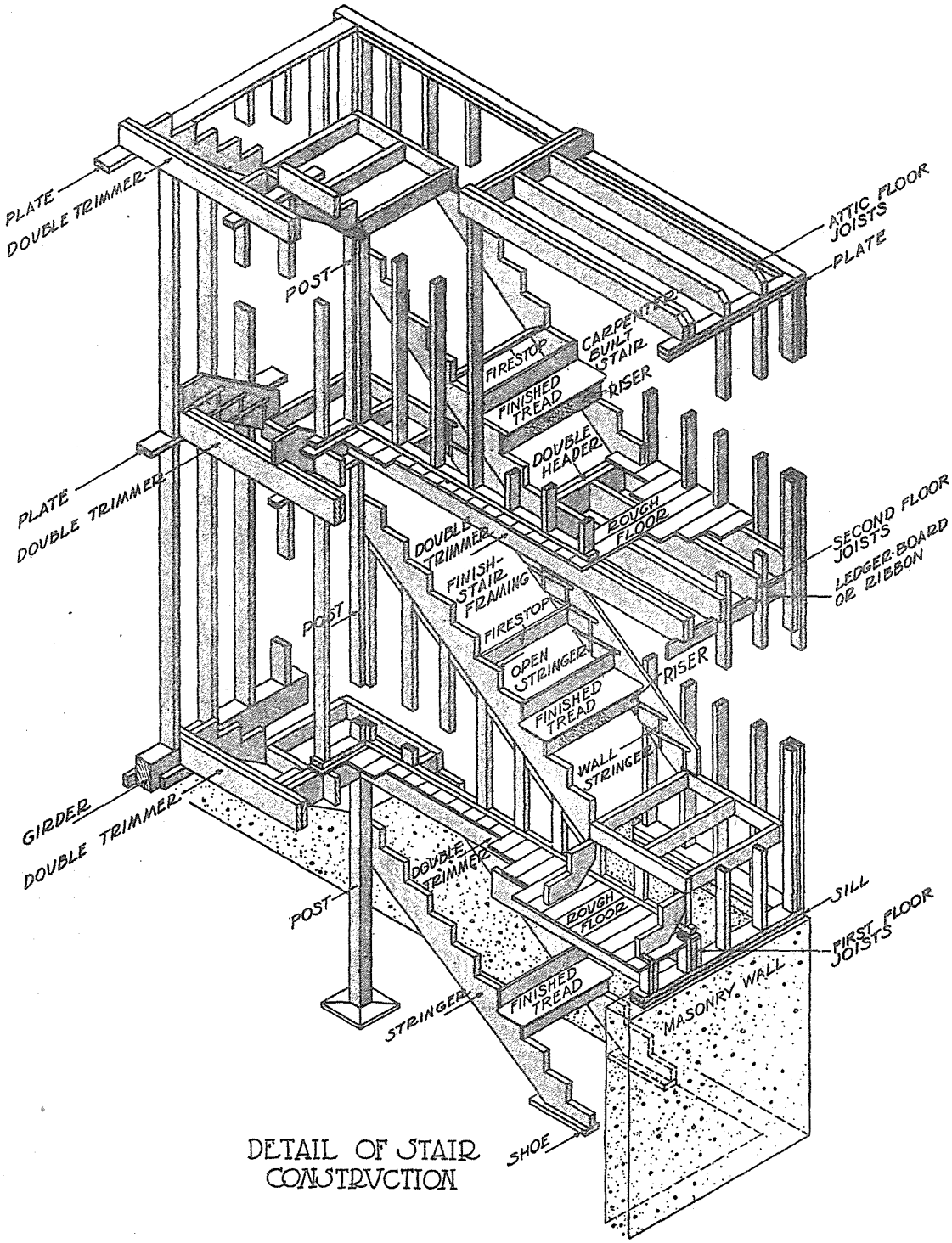
Metal lath comes in various widths depending upon the material from which it is made. Expanded metal is usually from 14 inches to 24 inches wide. It should not be of less weight than #27 U. S. gauge. Woven wire lath comes in various widths from 1 foot to 10 feet. The wire used should not be of less weight than #20 U. S. gauge. Metal lath must be galvanized or painted to prevent deterioration from rust.

Wallboards are often used as a substitute for plaster, although they are sometimes used only for insulating purposes. The main reason for their use is economy. Because of this, they are widely used for finishing attic spaces and basements, and for lining closets. Wallboards come in a variety of widths to provide a paneled effect when properly applied. Joints between boards must be covered by strips of molding.

94. Stairways

The specifications should describe the construction of stairways, and large scale, detailed drawings should illustrate each step of the construction. When joists are cut to provide an opening for a stairway, their supporting strength is weakened. This loss in strength must be regained by bracing or boxing. Double headers of the same size material as the joists are nailed to the cut end of the joists. The headers are supported by full length joists which have been doubled or tripled in width depending upon the load which the joists were originally intended to carry. Details of stairway framing are shown on Page 142.

Stair risers are usually 7 inches in height and should never exceed 8 inches. The treads may vary between 9 and 10 inches. The nominal thickness of risers is usually 1 inch and the nominal thickness of treads is usually 1-1/4 inch. Risers and treads should be tongued and grooved so that they can be mortised and tenoned to-



DETAIL OF STAIR CONSTRUCTION

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

STAIRWAY FRAMING DETAILS

gether at the building. Detailed stairway plans should show the number of risers, the width of the stairway and the details of joist framing around the stairwell.

Stairs are constructed in two ways; with the stringers cut and mitred so that the treads will extend over them, or boxed so that the treads will fit snugly inside of the outside stringer. They are further supported by a third stringer called a carriage. The distance between outside stringers and the carriages should not be more than two feet.

The under side of stairs should be finished in the same manner as the walls. Newel posts and railings should be fully detailed in the specifications and the working plans.

95. Roof Framing

A sufficient amount of pitch must be provided in all designs of roof framing. The minimum for shingle roofs should be one-quarter pitch or a rise of 6 inches in 1 foot. In snow areas the pitch should be increased to at least one-third or a rise of 8 inches in 1 foot. The size of material used for rafters depends upon the type of roof and upon the part of the country in which the building is located. The rafters must be strong enough to support the designed dead loads and any estimated snow loads that might be put upon them.

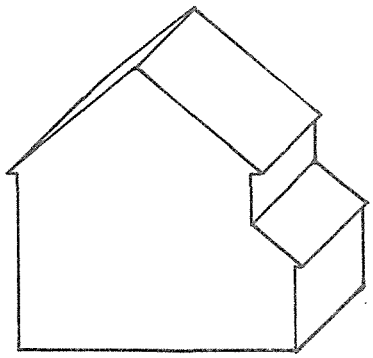
The simplest type of roof is the lean-to. It is usually used for porch roofs and in the construction of sheds. The gable roof is the most common tyep of roof used for the construction of dwellings and other buildings. It is of triangular section and has two slopes which meet in the ridge to form a gable. Rafters are supported at the lower end by the plates on top of the studding. At the upper end, the rafters are nailed to a ridge pole which runs the entire length of the roof. The ridge pole prevents the rafters from slipping past each other and makes a more solidly braced roof.

96. Attaching Rafters to Side Walls

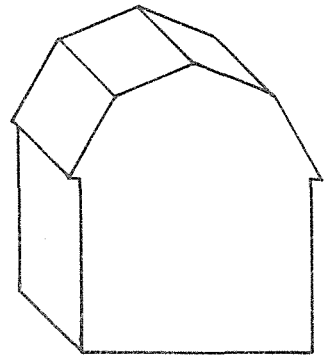
Unless additional space is required in the attics of buildings, the rafters are attached directly to the upper plate over the studding as shown in the illustration on Page 138. If additional attic space is required, the studs are usually carried higher than the attic floor level and the rafters are attached in a similar manner with the addition of a brace running to the floor joists. Rafters are usually notched where they fit on the wall plate.

97. Roof Sheathing

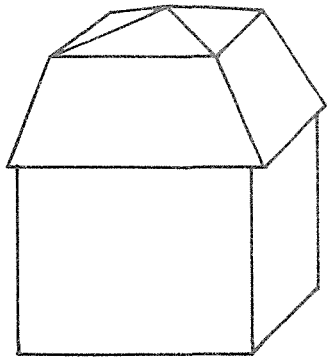
Roof sheathing is nailed directly on to the rafters, and the shingles or other roofing material is attached to the sheathing. Sheathing may consist of square edged boards laid close together or with an opening between them, or of tongue-and-groove or shiplapped boards. Solid sheathing is preferable to open spaced sheathing because of the additional insulation which it gives. Roofs and roofing materials are discussed in Chapter XIX.



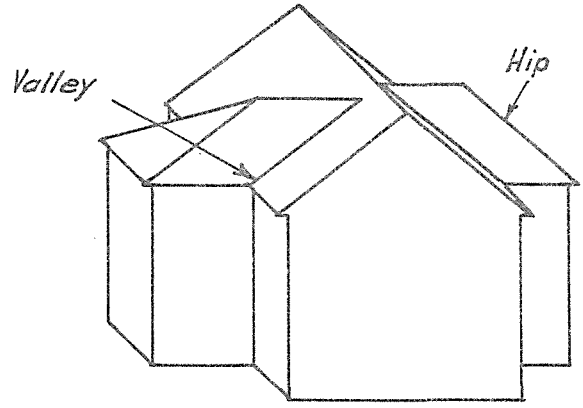
GABLE



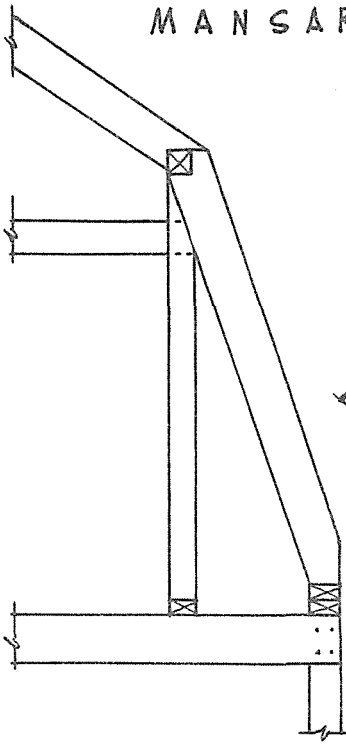
GAMBREL



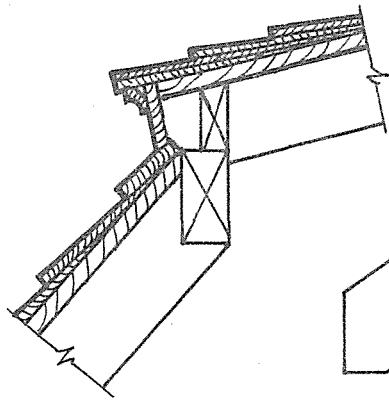
MANSARD



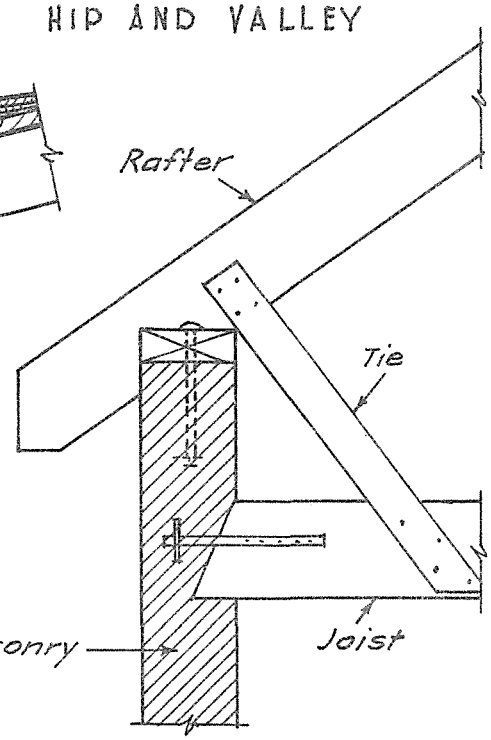
HIP AND VALLEY



FRAMING FOR MANSARD ROOF



GAMBREL
ROOF FINISH



TYING RAFTERS TO JOISTS

TYPICAL ROOF TYPES

98. Sub-Flooring

Sub-flooring is nailed directly to the floor joists and the finished flooring is attached to it. Material used for sub-flooring may be the same as that used for roof sheathing but is usually of a higher grade. It is preferably laid diagonally to help brace the building and to assure the builder of a smooth surface of the finished floor. A layer of felt paper or tarred roofing paper should be placed on the sub-flooring to provide for better insulation.

99. Finished Flooring

Good practice in building construction requires that the finished flooring be not installed until all other work has been completed. This helps to prevent damage to the flooring and also gives the plastering sufficient time to dry thoroughly. Cracks between the finished floor and the baseboard should be covered by some form of molding. Hardwood such as maple, birch, beech and oak, makes the best kind of floors, although some species of softwood such as Southern pine and Douglas fir are often used. Care should be exercised in the laying of hardwood flooring to prevent splitting of the boards. The correct sizes and kinds of nails are discussed in Chapter XXIV.

100. Building Paper

Modern construction requires that the outside walls and roofs of frame buildings be covered with some kind of impervious lining to prevent the infiltration of air and moisture. The paper is applied just before the outside finish or roofing is placed. Building paper should be tough and strong so that it may be handled easily without tearing. Fireproof asbestos sheathing paper is used to some extent but the most common type is a felt paper. All building papers should be applied in accordance with the recommendations of the manufacturer.

101. Outside Finish of Walls

The outside surface of frame buildings may consist of clapboard siding, shingles, stucco or other material. The kind used may depend upon the architectural effect desired, the location, or the cost. A greater variety of effects may be secured with the use of shingles, but their cost is usually higher than that of other finishing materials. A water table should be placed just above the foundation wall to prevent water from running between the wall and the foundation. The use of shingles is discussed in Chapter XIX. Other types of wood covering are discussed in Chapter VIII.

102. Stucco

Stucco finish is usually placed on wood frame buildings, although there are occasional instances where it is placed on brick of masonry buildings. If the building is to receive a stucco finish, it should be so designed that a minimum amount of water will be permitted to flow over the walls. This may be accomplished by the use

of wide, over-hanging roofs or drip grooves. It is better to apply stucco only to vertical surfaces because the possibility of water standing on the stucco will be eliminated. The preparation and application of stucco is discussed in Chapter XX.

103. Brick Veneer

Brick veneer construction may be made practically as rigid as solid brick wall. The veneering consists of a 4 inch brick thickness placed on the outside of and anchored to a frame wall. An air space of at least 1 inch should be left between the brick work and the sheathing. The air space should be properly flashed and drained at the sill line and should be vented at the attic line. All flashing and anchorage between the brick and the sheathing should be of non-corrodible metal. An illustration of a brick veneer wall is shown on Page 147.

104. Cornices and Gutters

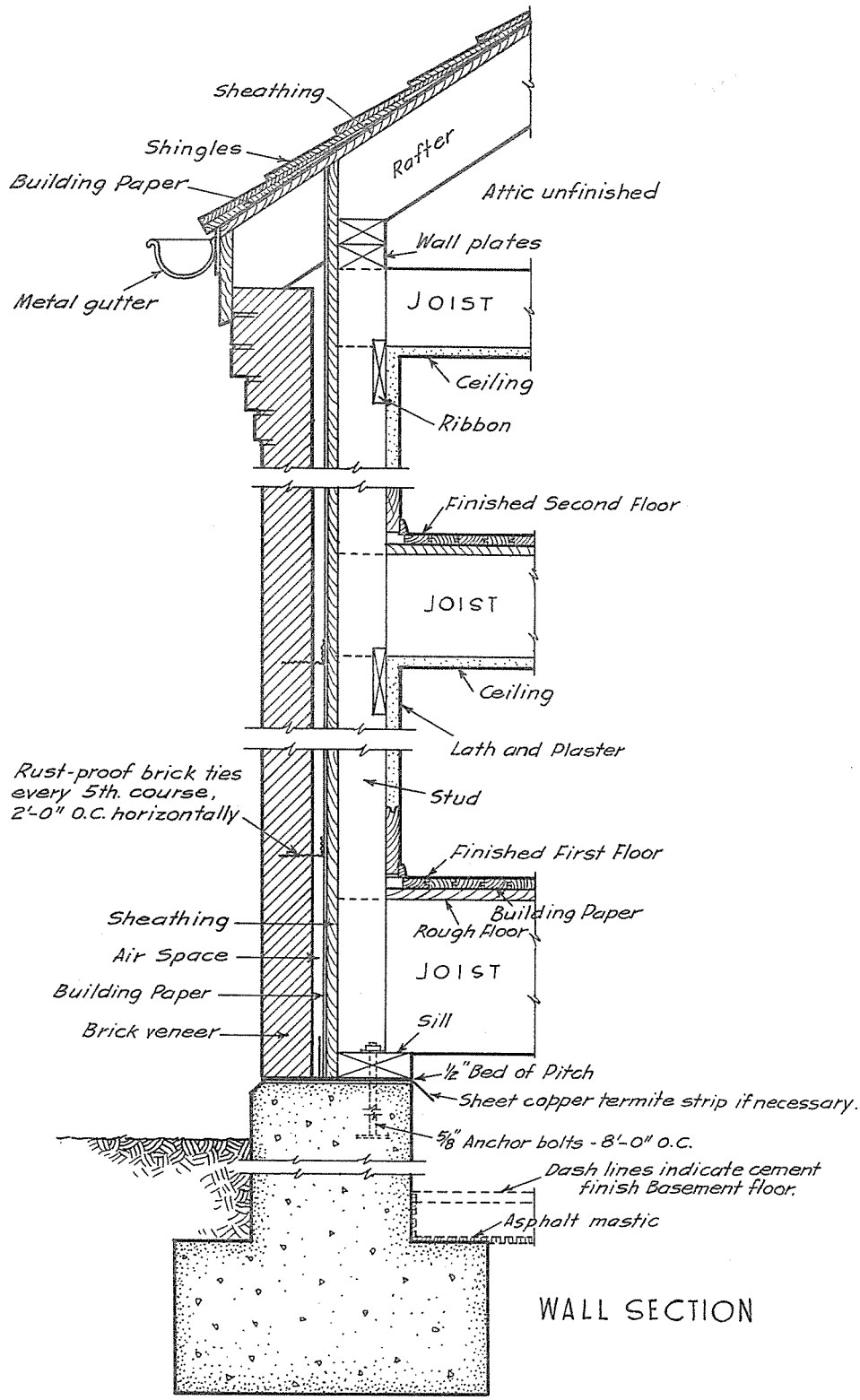
Cornices are used to furnish an architectural finish between the roof and the side wall of a building. There are many methods of constructing cornices and most of them use standard mill material. Gutters may or may not be used, depending upon the desires of the architect. In many regions wooden gutters are constructed. If these are made of durable wood and are properly maintained, they will usually last as long as the rest of the building. The location of the gutters depends upon the part of the country in which the building is constructed. In regions of heavy snows the gutter should be placed so that the outside edge will be a little lower than the projected roof slope. This will allow melting snow to slide over the gutter without damage to it. Illustrations of cornice and gutter construction are shown on Page 148.

105. Dormer Windows

Any window constructed in a roof, unless it is built flush with the roof, is called a dormer window. They may be built for architectural effect or to supply light in an attic. If the use of dormer windows is desired, an opening should be left in the roof and the dormer built above the opening. All connections between the dormer and the roof should be properly flashed to prevent leakage into the building. Framing details of dormer construction are shown on Pages 149 and 150.

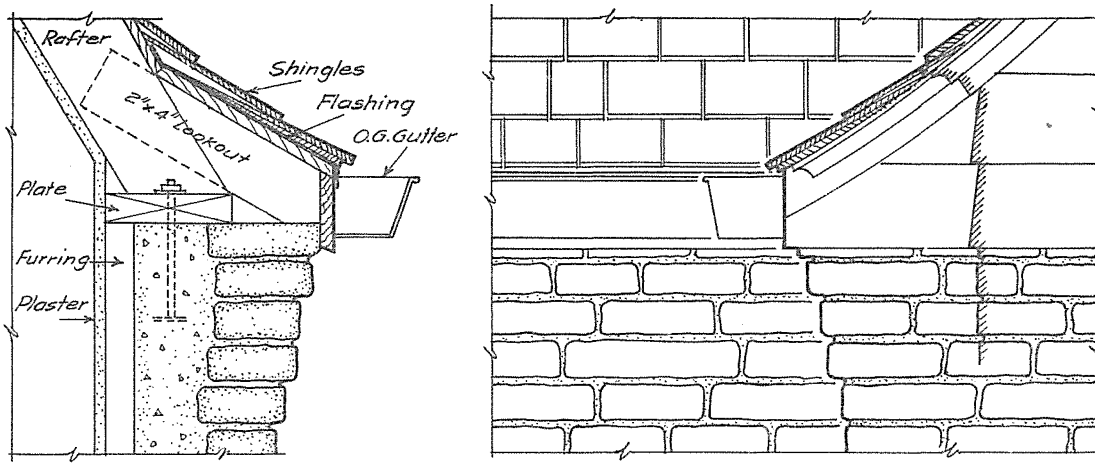
106. Skylights

Skylights are generally built to supply light to parts of an attic where the construction of a dormer window would not be justified. Skylight frames are usually raised a little distance above the roof line to prevent them from being covered by snow. Means must be provided for draining off the moisture which condenses on the glass. This is quite an important matter in the construction of large skylights, and should be carefully considered in the plan details.

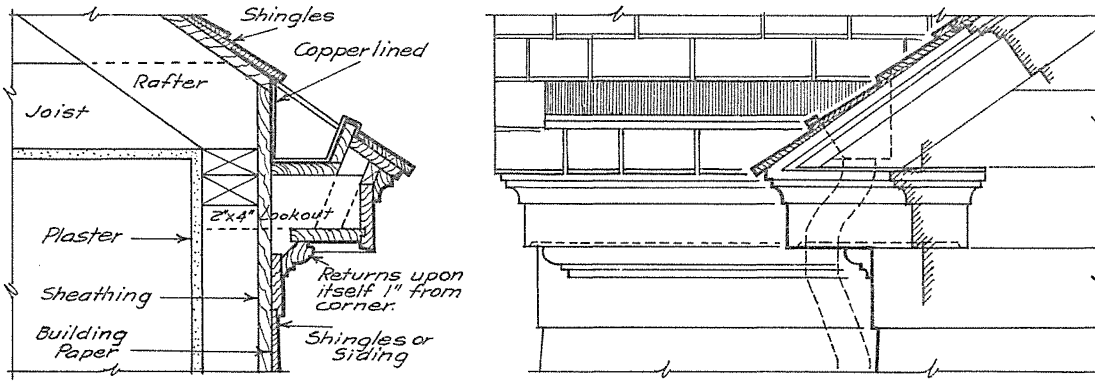


WALL SECTION

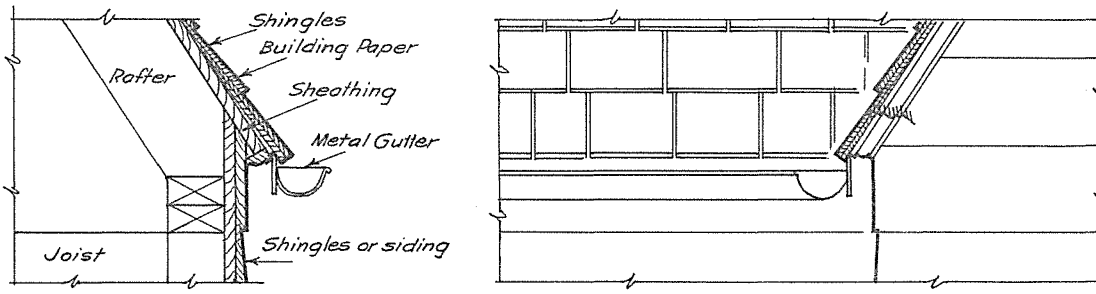
BRICK VENEER WALL



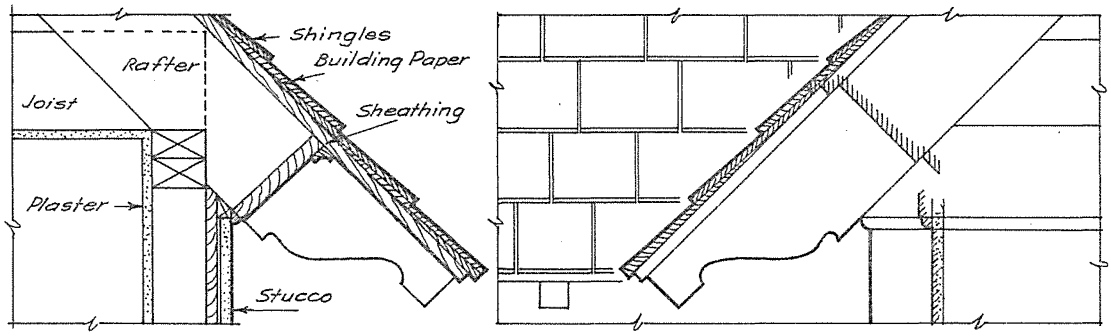
O.G. GUTTER



BUILT-IN OR BOX TYPE GUTTER

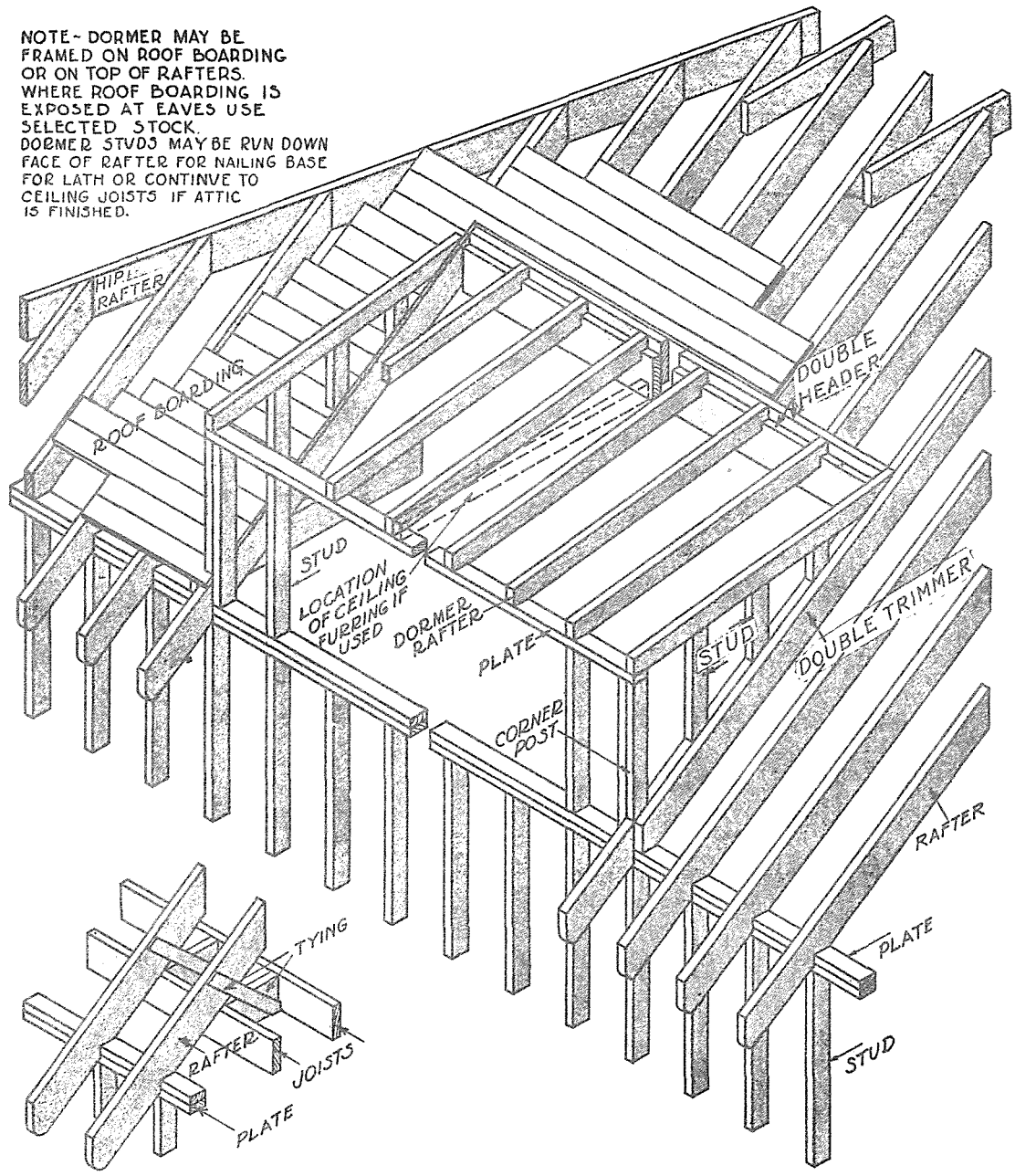


HANGING GUTTER



EXPOSED RAFTER CORNICE

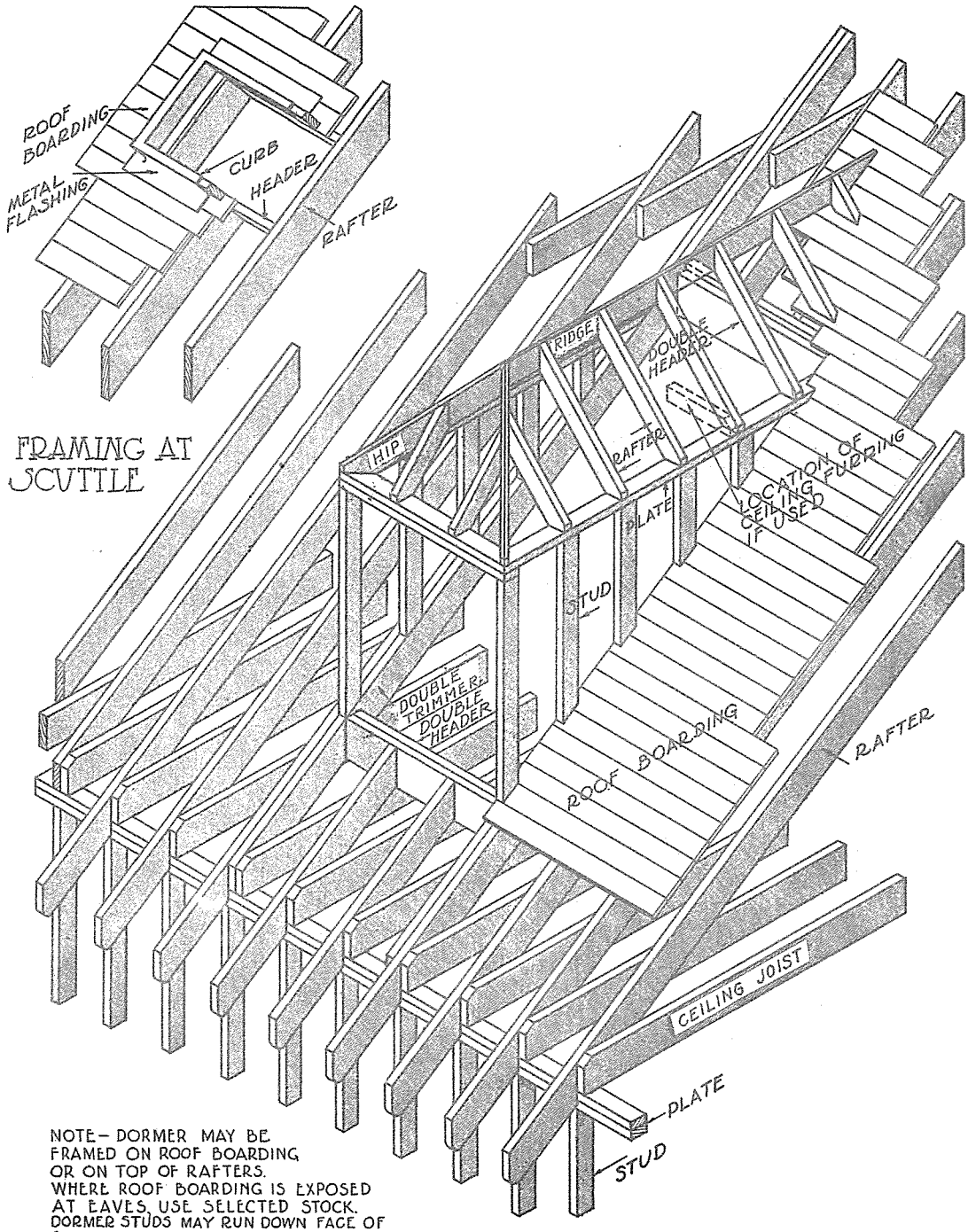
CORNICE AND GUTTER CONSTRUCTION


NOTE- DORMER MAY BE FRAMED ON ROOF BOARDING OR ON TOP OF RAFTERS. WHERE ROOF BOARDING IS EXPOSED AT EAVES USE SELECTED STOCK. DORMER STUDS MAY BE RUN DOWN FACE OF RAFTER FOR NAILING BASE FOR LATH OR CONTINVE TO CEILING JOISTS IF ATTIC IS FINISHED.
HIP RAFTER
ROOF BOARDING
DOUBLE HEADER
STUD
LOCATION OF CEILING FURRING IF USED
DORMER RAFTER
PLATE
STUD
DOUBLE TRIMMER
CORNER POST
RAFTER
PLATE
STUD
TYING
RAFTER
JOISTS
PLATE

METHOD OF BRACING ROOF WHERE RAFTERS ARE AT RIGHT ANGLES TO JOISTS

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

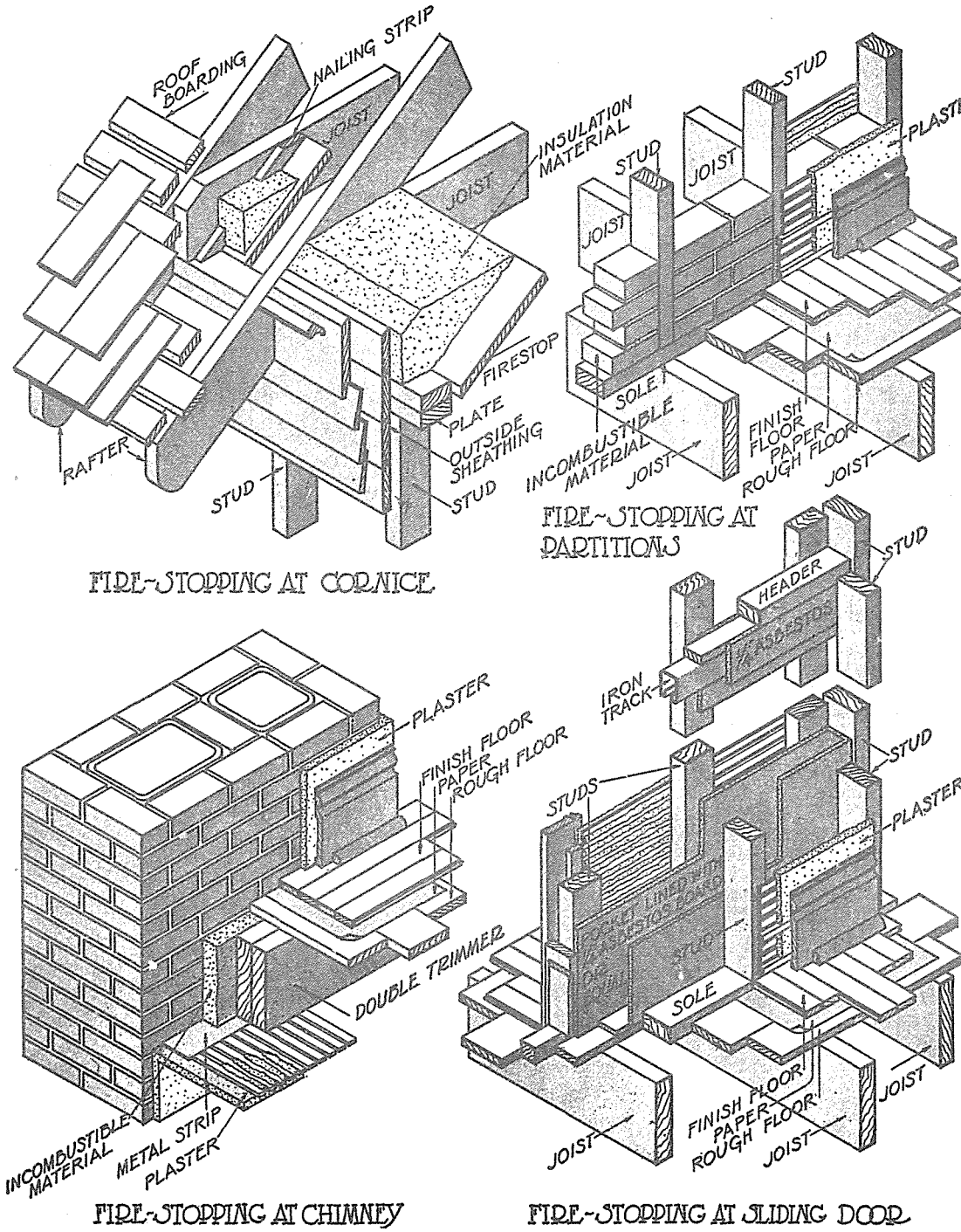
DORMER WINDOW FRAMING



NOTE– DORMER MAY BE FRAMED ON ROOF BOARDING OR ON TOP OF RAFTERS. WHERE ROOF BOARDING IS EXPOSED AT EAVES, USE SELECTED STOCK. DORMER STUDS MAY RUN DOWN FACE OF RAFTER FOR NAILING BASE FOR LATH OR CONTINUE TO CEILING JOISTS IF ATTIC IS FINISHED.

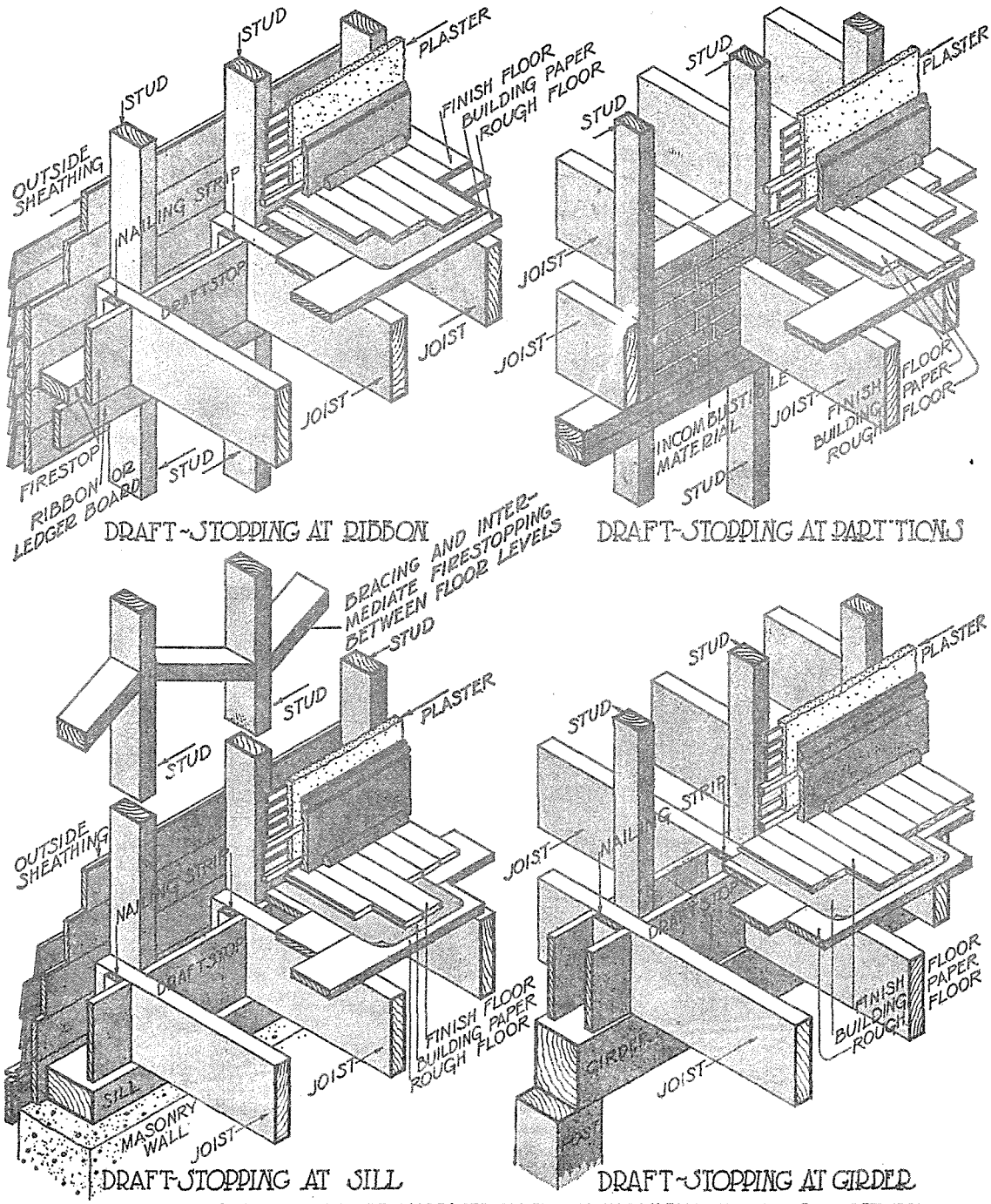
BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

DORMER WINDOW FRAMING



BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

FIRE STOPPING DETAILS



NOTE ~ EFFICIENCY OF FIRESTOPPING MAY BE INCREASED BY PLACING INCOMBUSTIBLE MATERIAL BETWEEN WOOD FIRESTOP MEMBERS.

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

DRAFT STOPPING DETAILS

107. Fire Stops.

Fire stops are used to prevent the immediate passage of flame from one floor to another. All concealed open spaces should be provided with occasional stops. These may consist of solid wood blocks or non-combustible materials such as mineral wool, concrete, tile or mortar. Fire and draft stopping details are illustrated on Pages 151 and 152.

108. Flashing.

Strips of metal which are used to provide watertight joints are called flashing strips. They are very necessary around chimneys, dormer windows and all openings in a building. Flashing strips are usually of copper, tin, zinc, lead or galvanized iron. The use of copper is generally preferred because of its long life without appreciable corrosion. Flashing details are illustrated on Pages 303, 304, 305, and 306.

109. Tile Floors.

Tile floors are usually placed in bathrooms of modern dwellings Tile is laid in mortar placed on top of a concrete floor base. The concrete floor base is laid over solid sheathing or sub-flooring with a layer of building paper between the concrete and the wood. Joists immediately under the concrete floor must be thoroughly braced and bridged to support the load which will be placed upon them. They should be framed so that there will be a minimum amount of cutting for the accommodation of soil and water pipes. If tile floors are installed in bathrooms above the first floor, a watertight lead pan should be placed on the wood sub-flooring before the concrete is poured. The edges of the pan should extend up at least 6 inches on the walls to prevent leakage to the floor below.

CHAPTER XI - HEAVY TIMBER CONSTRUCTION

110. General.

Heavy timber construction is generally intended to include all types of work where timber 6" x 6", and larger, are used. In Forest Service work, the construction of warehouses, garages, equipment buildings, bridges and trestles comes under this heading. Numerous descriptions and illustrations of recommended framing methods will be given in this chapter.

111. Mill Construction.

The term "mill construction" formerly meant that type of construction where the walls were made of brick or stone masonry and all framing for floors and roofs was of heavy timbers. Recent developments in design have tended to give a different meaning to this term. In some parts of the country mill construction means that the buildings are constructed of steel. In other parts of the country the entire structure may be of wood and still be termed mill construction.

For the above reasons the term "mill construction" alone is seldom used to designate the type of construction to be employed in Forest Service work.

112. Common Types of Construction.

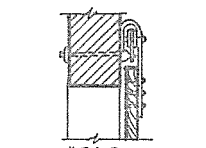
To more or less standardize the type of construction by name, modern practice has divided heavy timber construction into three general types. The main difference between the three types is in the details of floor construction. Each type is briefly described below.

A. Standard Mill Construction.

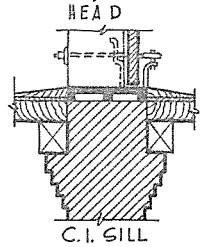
In the standard mill or girder type of construction the maximum column spacing was originally set at 12 feet in both directions. Modern design has changed this spacing so that columns are now placed as much as 20 feet apart. Floors in this type of construction are of heavy material laid flat upon large girders which are spaced not less than 8 feet apart. Extra care should be exercised in the design of the fastening of the beams to the walls and to each other. This is very important in securing rigidity in finished structures. Illustrations of standard mill construction details are shown on pages 156 and 157 .

B. Semi-mill Work.

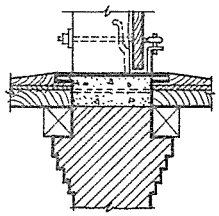
In the semi-mill or beam and girder type of construction the heavy floor is supported by beams between the girders. The beams are



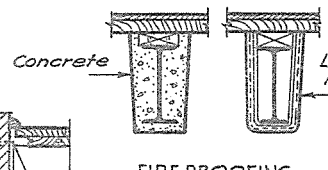
HEAD



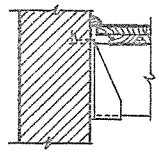
C.I. SILL



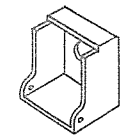
SECTION THRU FIRE DOORS



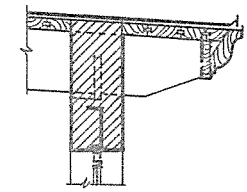
FIRE PROOFING STEEL BEAMS



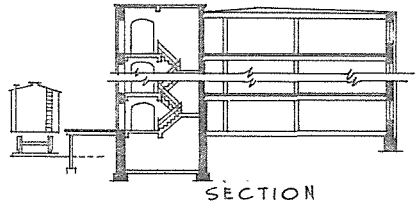
WALL HANGER



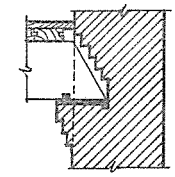
WALL BOX



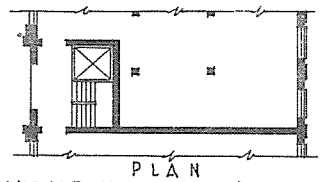
CORNICE



SECTION

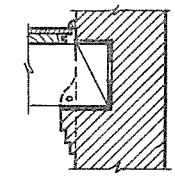


C.I. PLATE



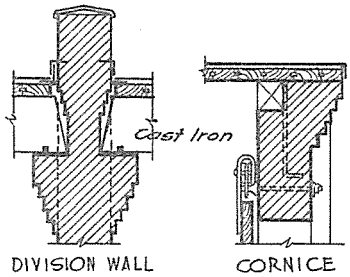
PLAN

STANDARD MILL CONST. BUILDING



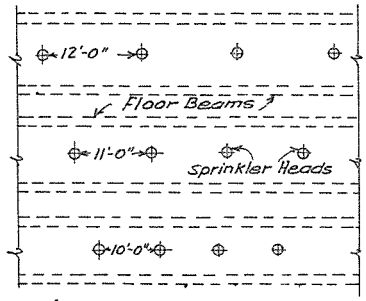
C.I. WALL BOX

WALL SECTION

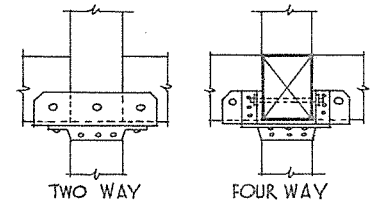


DIVISION WALL CORNICE

ONE STORY MILL CONSTRUCTION



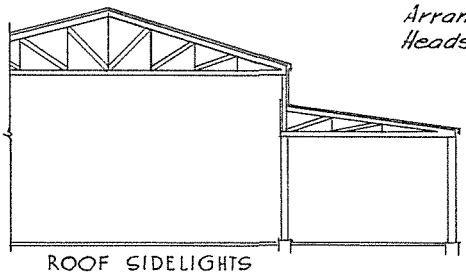
Arrangement of Sprinkler Heads for given Beams



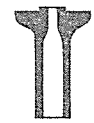
TWO WAY FOUR WAY

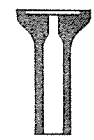
STEEL POST CAPS

BY COURTESY OF NATIONAL LUMBER MANUFACTURERS ASSOCIATION

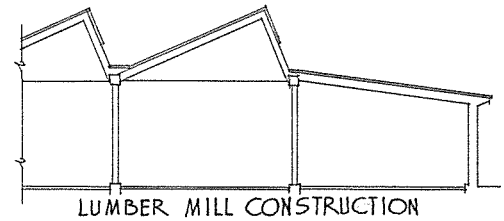


ROOF SIDELIGHTS

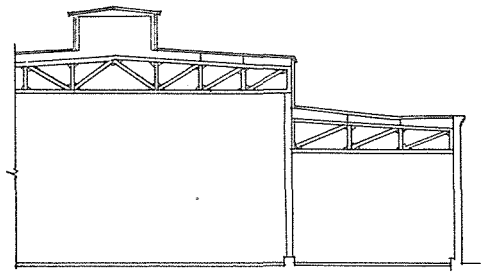




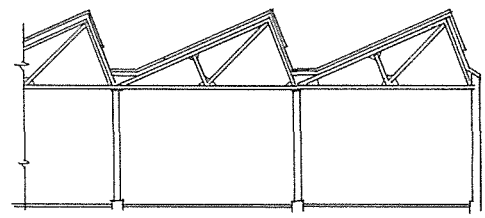
PINTLES AND CAP



LUMBER MILL CONSTRUCTION

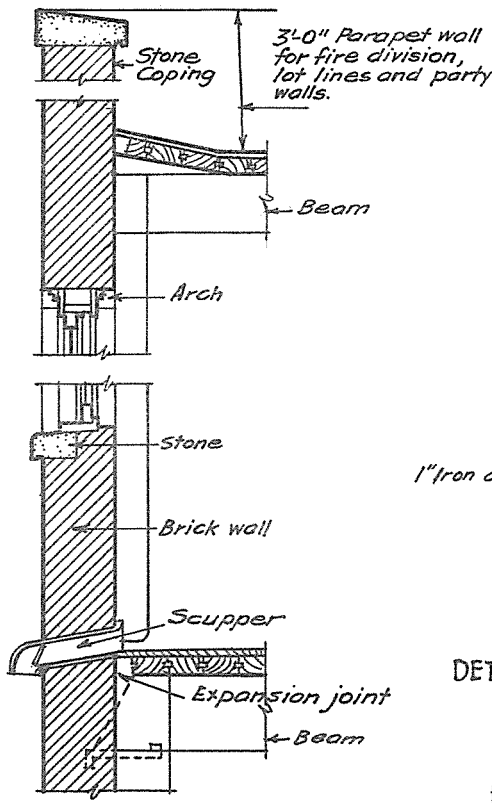


ROOF SIDELIGHTS & MONITOR TYPES

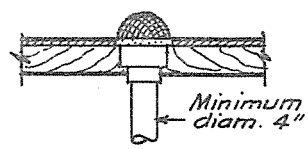


STEEL TRUSS WITH LUMBER MILL ROOF

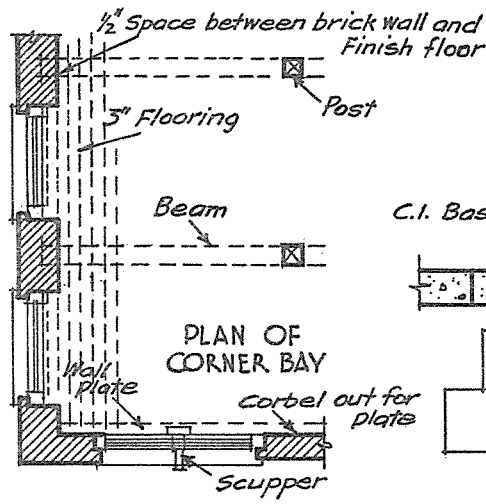
STANDARD MILL CONSTRUCTION

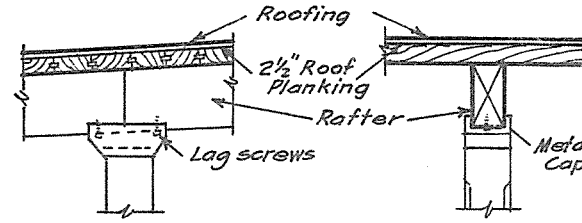


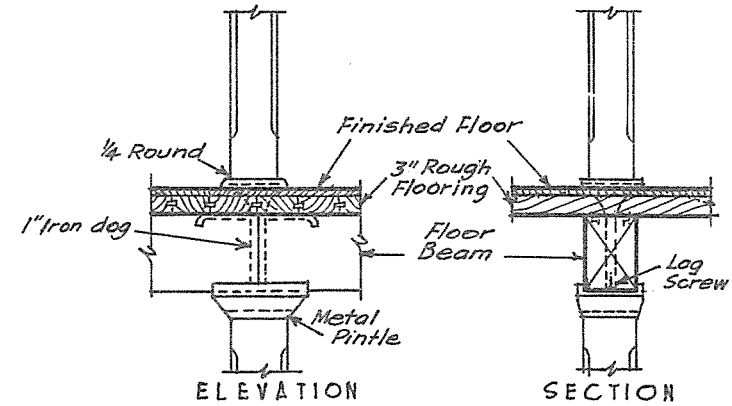
SECTION THRU WALL SHOWING EXTERIOR SCUPPER



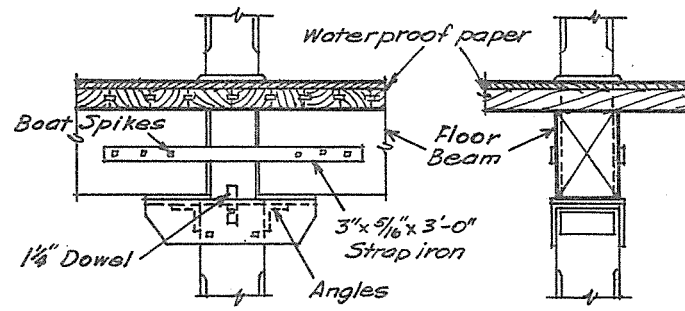
DETAIL OF INTERIOR SCUPPER





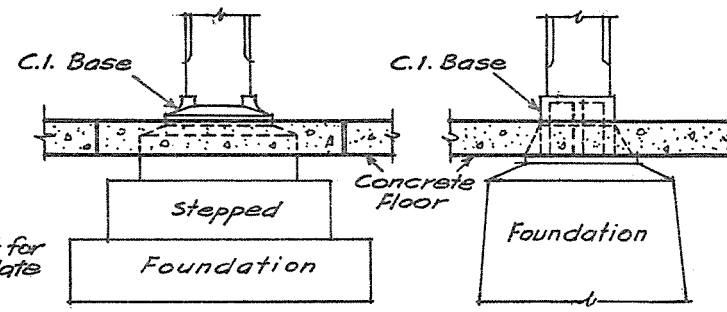


DETAIL OF FLOOR BEAM AT POST USING METAL PINTLE



DETAIL OF FLOOR BEAM AT POST USING ANGLE IRON POST CAP

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION



TYPICAL POST DETAIL

STANDARD MILL CONSTRUCTION

spaced not more than 4 feet apart and the girders are spaced as far apart as the loading will allow. In the better type of semi-mill construction the floor beams rest directly on top of the girders. In the other types of semi-mill construction the tops of the floor beams are only about one inch above the top of the girders, and the beams are supported by some form of metal stirrup. This type of construction is frowned upon by Insurance Underwriters because of the extra fire hazard which may develop due to the failure of the material in the stirrup.

Illustrations of semi-mill construction are shown on pages 159 and 160 .

C. Laminated Mill construction

The laminated mill type of construction is an off-shoot of standard mill construction which was developed to take care of heavier loads. The floors of heavy plank are laid on edge and are supported by girders which are spaced not less than 12 feet apart.

The best type of construction requires that the flooring timbers be either 6 or 8 inches wide and not more than 2 or 3 inches thick. The boards should be dressed only on the edge so that they will not set so tightly together as to prevent a slight circulation of air between them. The boards should be nailed together at intervals of about 18 inches to provide rigidity.

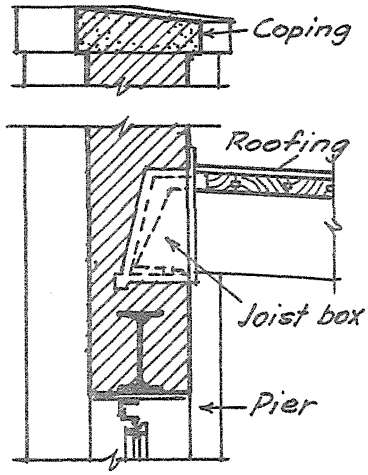
An illustration of laminated mill construction is shown on page 161 .

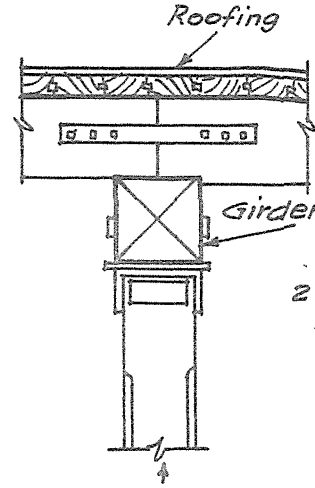
113. Design Factors.

Heavy timber construction is generally thought of as a slow burning type of construction. This means that the timbers involved are so large that there will be more resistance to combustion than there would be in light members. Large timbers do not ignite readily and even if exposed to open flames, tend to char rather than to burn. All sides of heavy timbers should be smooth. The extremely high factor of safety used in the design of columns, beams and girders, allows for considerable charring before the members are seriously damaged.

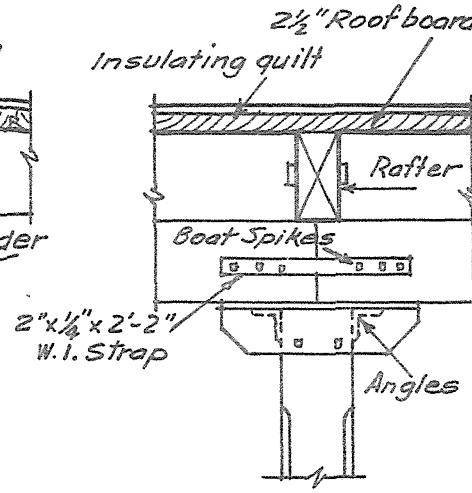
The minimum size of columns, beams, and girders and the minimum thickness of floors for heavy construction are established in most places by building codes and insurance specifications. Even in places where these sizes are not regulated, good building practice and common sense should govern the sizes used. Girders and beams should never be less than 6" x 6". Factors of weight, deflection, vibration, and impact must be considered in the design.

It is preferable that girders be of a single piece of material, but where the required size is too large to be cut off a single log, the girder may be built up of a number of pieces by bolting the pieces together. In all cases of this kind, the larger dimension should be

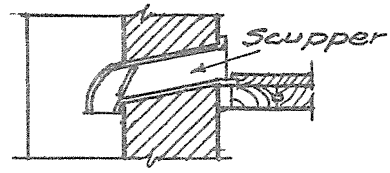


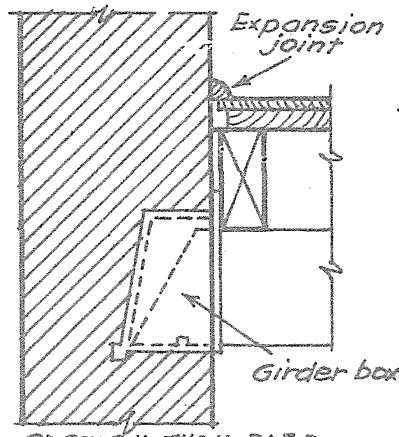


SECTIONS THRU GIRDERS

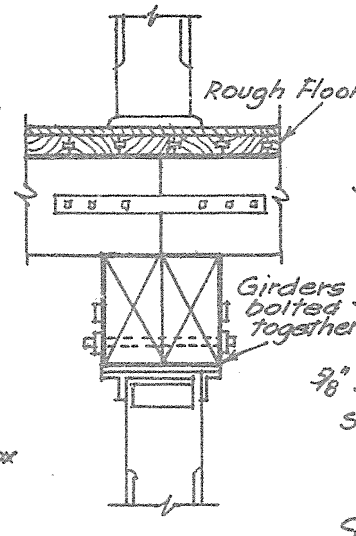


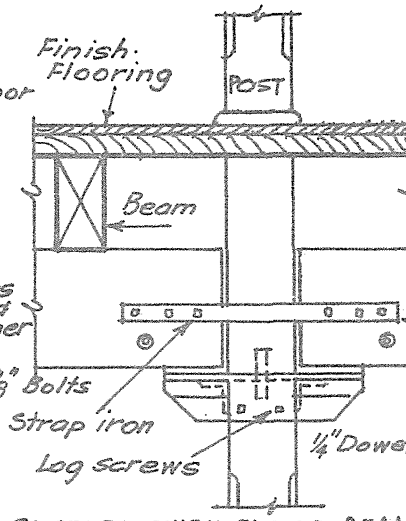
BY COURTESY OF NATIONAL LUMBER MANUFACTURERS ASSOCIATION



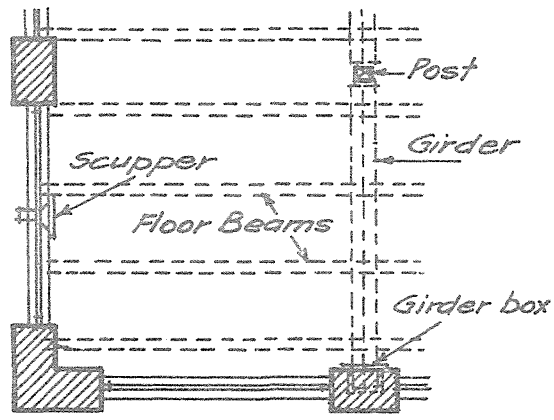


SECTION THRU PIER

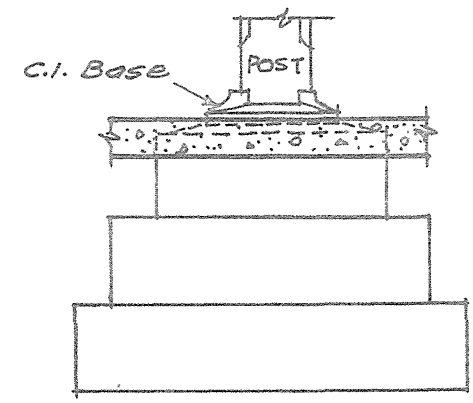




SECTION THRU FLOOR BEAMS

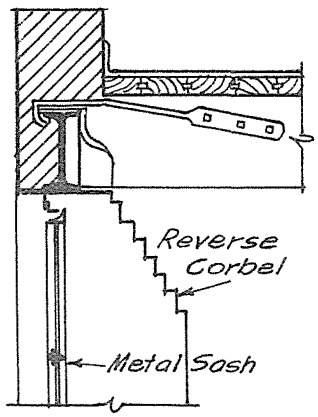


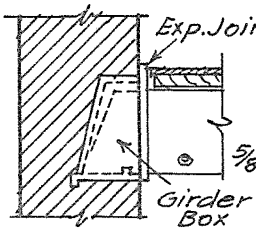
PLAN OF CORNER BAY



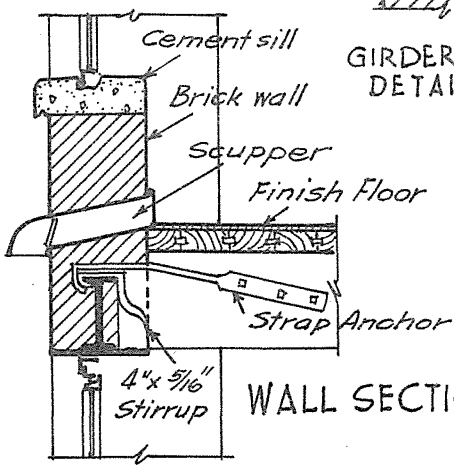
TYPICAL POST DETAIL

SEMI-MILL CONSTRUCTION

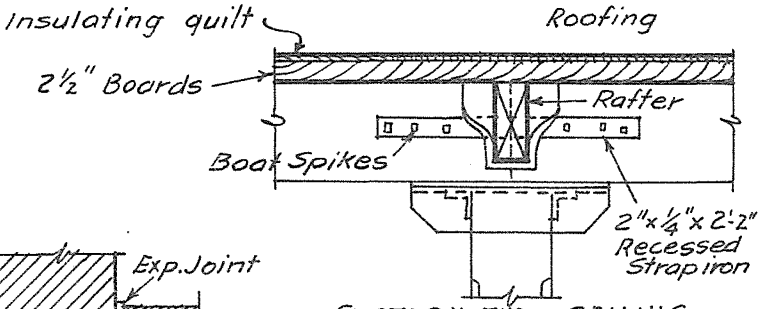




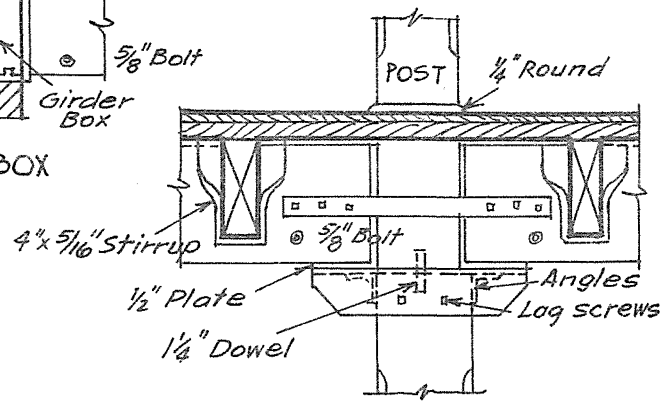
GIRDER BOX DETAIL



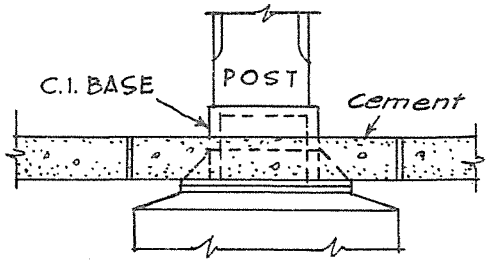
WALL SECTION



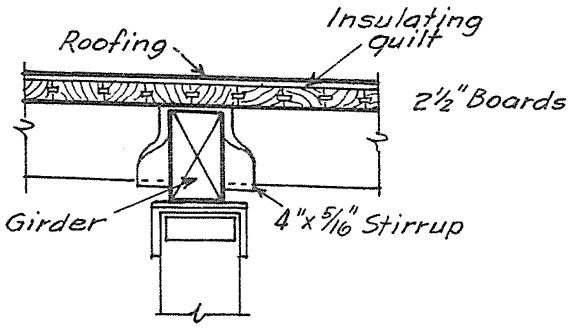
SECTION THRU CEILING

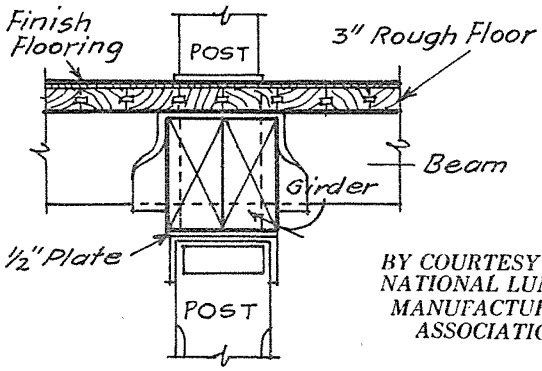


SECTION THRU FLOOR BEAM



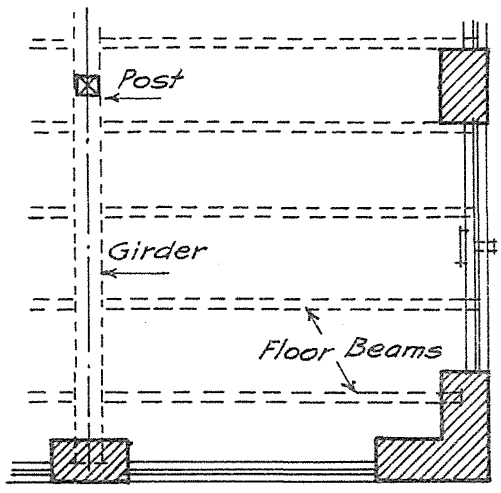
TYPICAL POST DETAIL





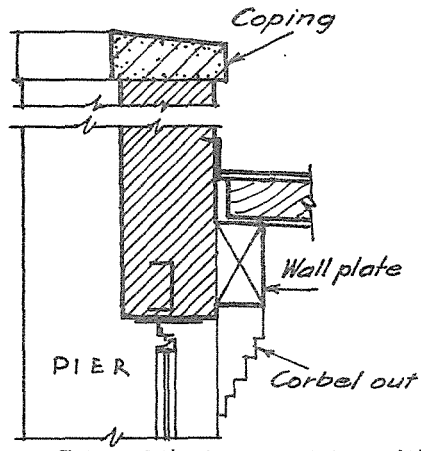
BY COURTESY OF NATIONAL LUMBER MANUFACTURERS ASSOCIATION

SECTION THRU GIRDER

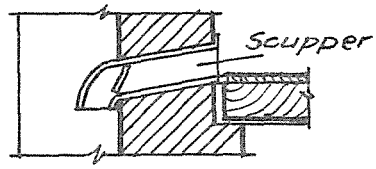


PLAN OF CORNER BAY

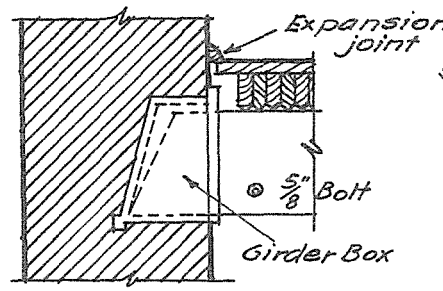
SEMI-MILL CONSTRUCTION



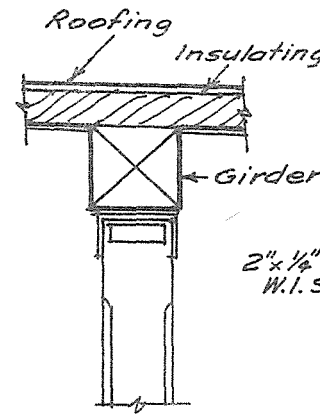
SECTION THRU WINDOW

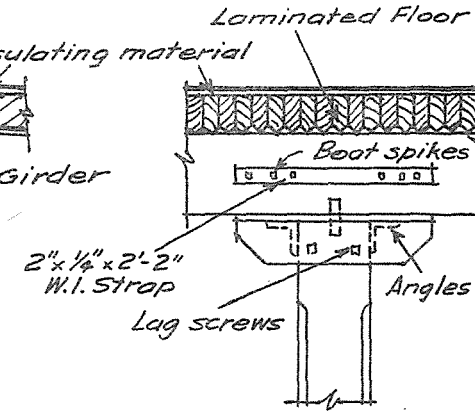


SCUPPER DETAIL



SECTION THRU PIER





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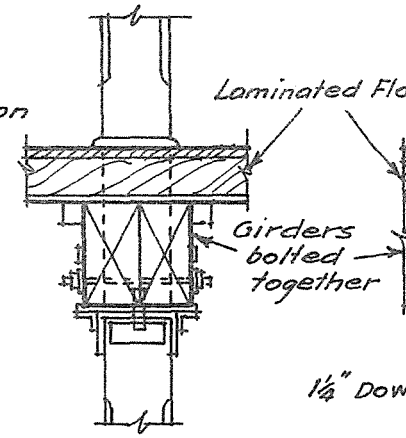
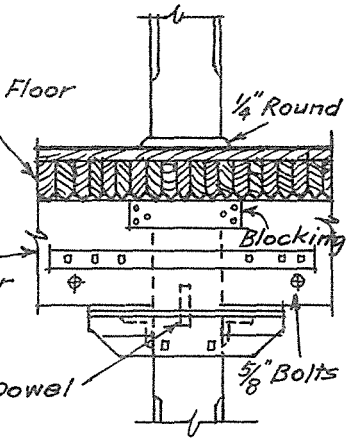
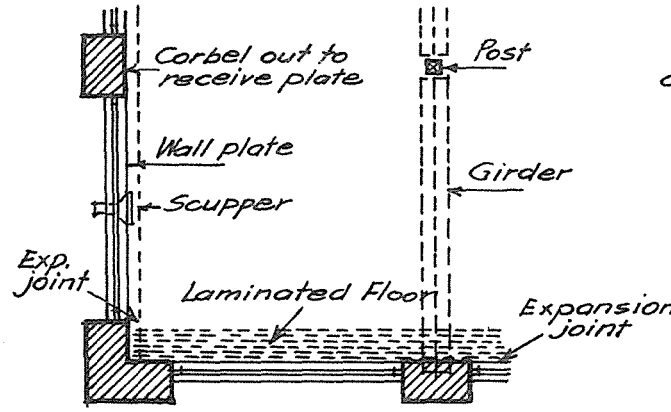


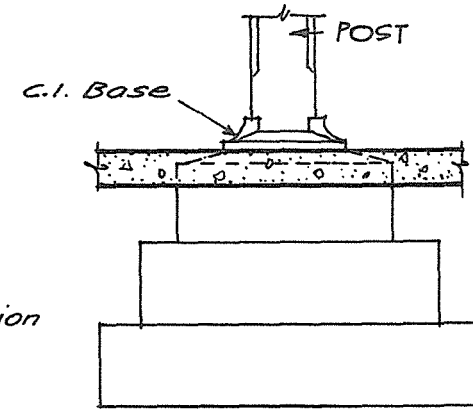
SECTION THRU GIRDER



SECTION THRU LAMINATED FLOORING



PLAN OF CORNER BAY



TYPICAL POST DETAIL

LAMINATED MILL CONSTRUCTION

placed vertical. Floors are usually required to be of not less than 3 inch material if laid flat. A top floor of thinner material is usually placed for a better wearing surface.

Roofs are generally designed to be nearly flat with only enough pitch to allow water to run off. A pitch of 1/4 to 3/4 inch per foot is usually sufficient. Roofs should be covered with non-combustible material such as metal, tile or asbestos. Design data for roof construction may be obtained from reliable handbooks.

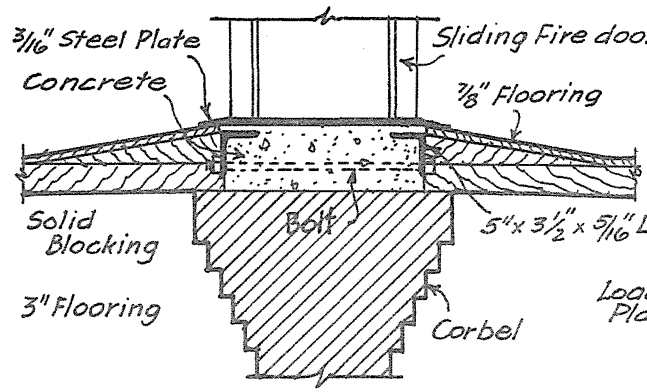
114. Column Connections.

The size of columns used in heavy timber construction is not usually the result of design, but is dependent upon the minimum size of the girders which rest upon them. In this connection, smaller columns may be used if some sort of a cap is provided. The most suitable type is made of metal because of the tendency of wood to shrink. Even though the column is of the same size as the width of the girder, it is good practice to use a bolster or cap to provide sufficient bearing area for the ends of the girder.

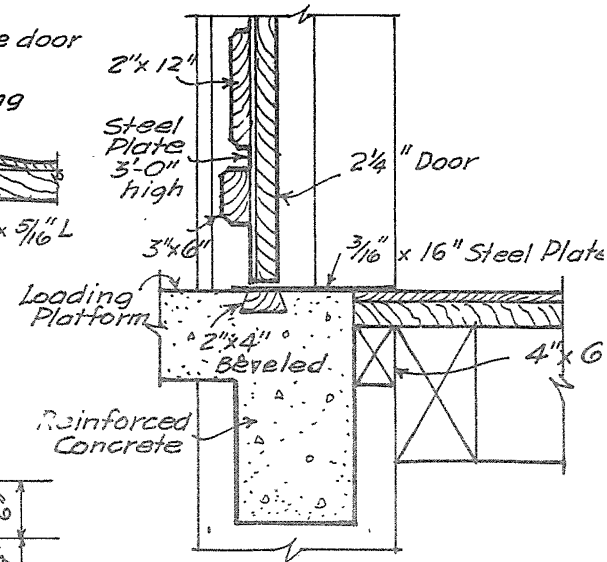
Columns should rest on each other from top to bottom of the building, but they should not pass through the floors and between the ends of the beams. To obviate this type of construction the use of pintles and post caps is necessary. Pintles or short cast iron columns should connect between the top of one column and the bottom of the one directly above it. Cast iron has a relatively high compressive strength and for this reason the pintles do not need to be of a very large diameter. The pintle passes through the ends of the beams which butt against each other and half of the hole which accommodates it is in each of the beams. The pintle is supported by a post cap which rests on the top of one column and in turn supports a post cap which is placed under the bottom of the column above. Column connections are illustrated on page 164.

115. Beam and Girder Connections.

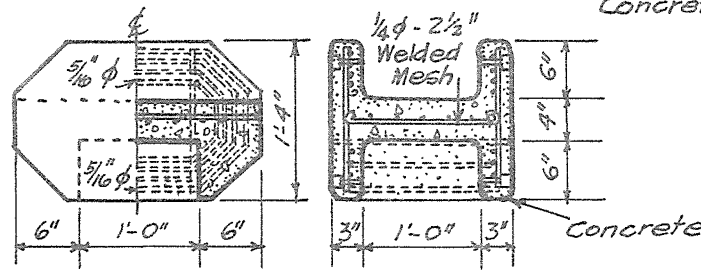
The most satisfactory method of supporting floor joists is to have them rest directly on the beams or girders. This method of construction is usually as cheap or cheaper than other methods if the building is to be not more than two stories high. Each time the joist is raised above the girder, the height of the wall is increased the same amount as the depth of the girder. For this reason the use of special metal joist hangers is found more economical. The joist hangers most commonly used are of two types. One type is connected to the girder by a nipple which is inserted in a hole bored through the girder. The other type is secured to the girder by a strap which passes over the top. Joist hangers should not be used indiscriminately, but should be so designed to eliminate as far as possible, failure of the metal due to the loads which are placed upon it.



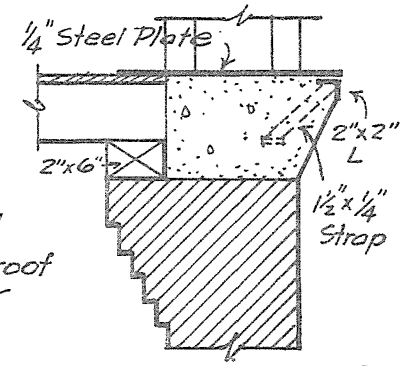
FIRE DOOR DETAIL



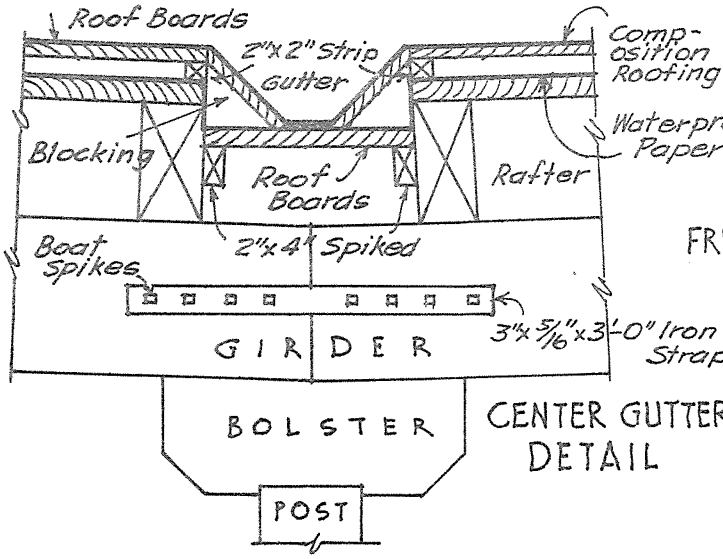
BUMPER DOOR DETAIL



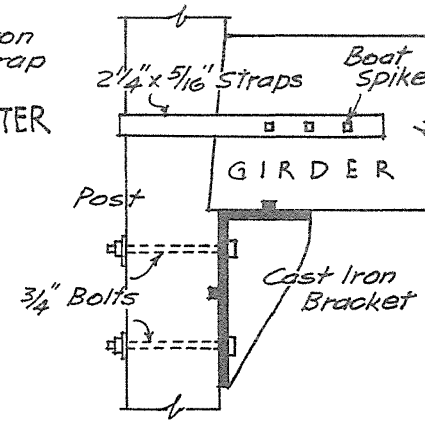
REINFORCED CONCRETE POST CAP



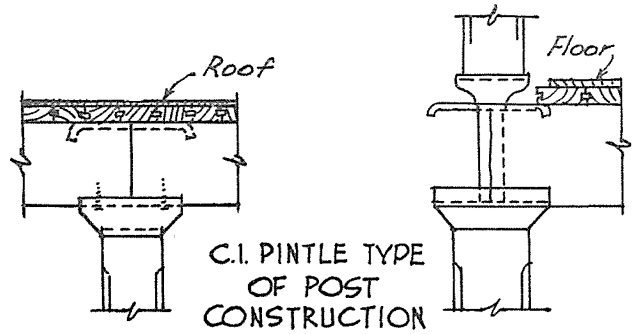
FREIGHT ELEVATOR DOOR SILL



CENTER GUTTER DETAIL



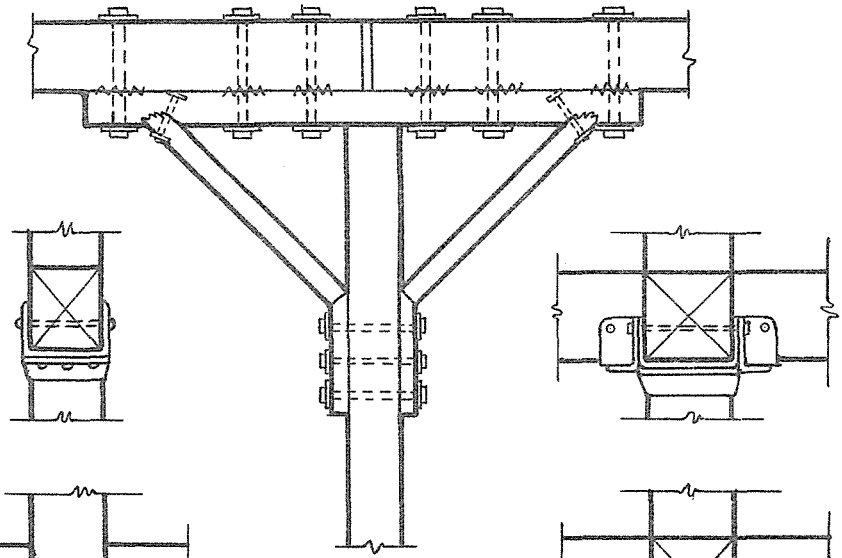
BRACKET DETAIL



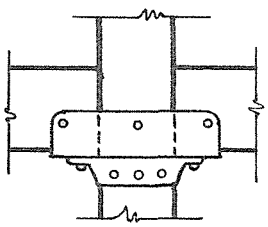
C.I. PINTLE TYPE OF POST CONSTRUCTION

BY COURTESY OF NATIONAL LUMBER MANUFACTURERS ASSOCIATION

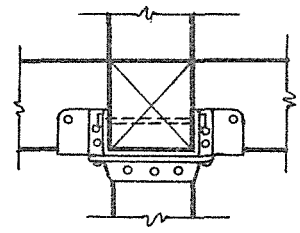
MISCELLANEOUS DETAILS



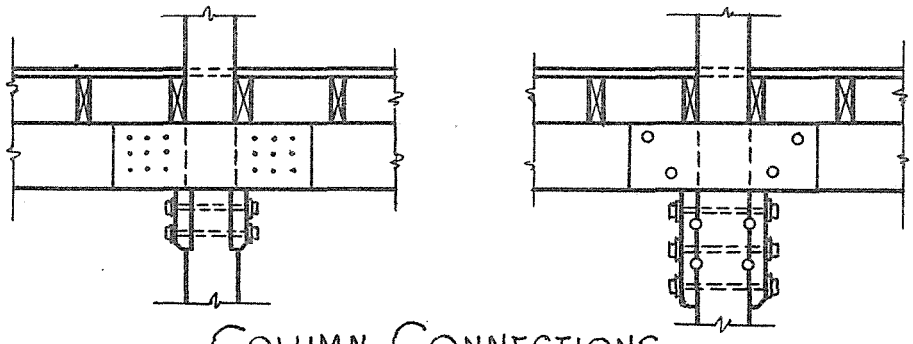
GIRDER SUPPORT



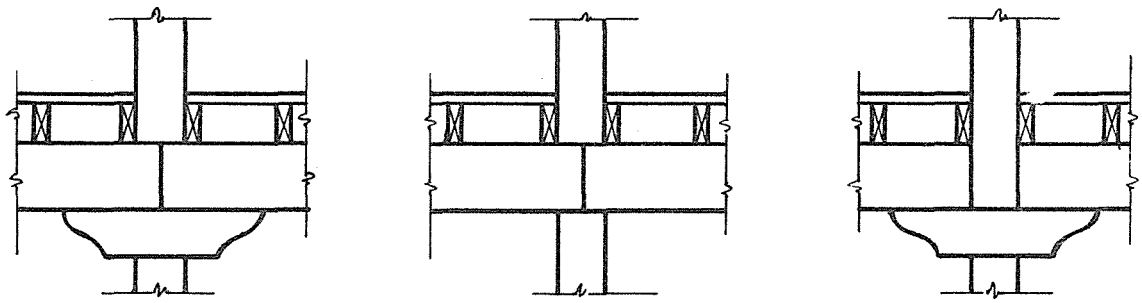
STEEL POST CAPS
(2-Way)



STEEL POST CAPS
(4-Way)



COLUMN CONNECTIONS
(Ceiling height not of importance)



DEFECTIVE CONNECTIONS

COLUMN CONNECTIONS

Beams and girders may be connected to walls by the use of stirrups or by insertion in the walls themselves. Where beams and girders butt together over columns, connections may be made by the use of plates, either metal or wood, or by the use of angles which are also connected to the bolster or cap on the top of the column. In some types of construction the girders do not rest on top of the column, but are connected to it by the use of stirrups.

116. Joints.

Timbers may be joined lengthwise in a number of ways. The most common types of tension and compression joints are lapped, fished, scarfed, and ring connected. The common fish joint is extensively used in compression, while the tabled fish joint may be used for either compression or tension. The ordinary scarfed joint known as a half-lap, makes an excellent compression splice, but the oblique scarf joint has the greater structural strength. Split ring connected joints are effective in tension. Illustrations of various kinds of joints are shown on pages 166 and 167. A more detailed discussion of joints is given in the Wood Handbook.

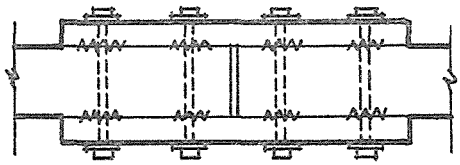
117. Modern Connectors.

Modern connectors consist of metal rings or plates and wood discs which are embedded partly in each of adjacent members and transmit the load from one to the other. The simplest explanation of their action is that they function as a dowel or a key. There are many different types in use in the United States, and several have been tested in the Forest Products Laboratory. Descriptions and illustrations of many types are shown in the Wood Handbook. Some details are shown on page 168, of this handbook.

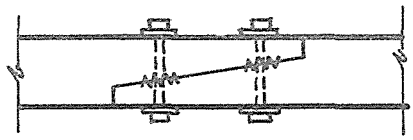
118. Bridges and Trestles.

The safety and stability of bridges and trestles is largely dependent on the underlying foundation upon which they rest. The bearing power of the soil at all bridge locations should be determined before any work is started. Test borings should be made and the cores from the boring should be examined for stability. In some cases it may be necessary to drive pilings to obtain a support for concrete or masonry piers. In other cases bed rock may be sufficiently close to the surface so that the piers can rest upon it.

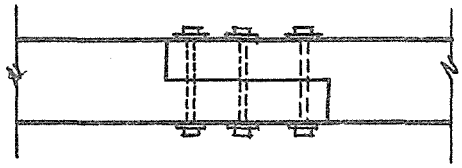
Concrete piers and abutments should be carefully designed according to the instructions and specifications given in Chapter XIV. In certain places the use of wooden trestles is more economical than the use of heavier bridges. Most trestles are supported on piles. The subject of piles and pile driving is discussed in Chapter V. All members of wooden bridges and trestles are connected by bolts, drift pins, lag screws, or boat spikes. Bolt holes should be bored 1/16" larger than the bolts to be placed in them. Holes for drift pins and lag screws should be from 1/16 to 1/8 inch smaller than the pins or screws. Floors are usually attached by the use of boat spikes, for which no hole is necessary.



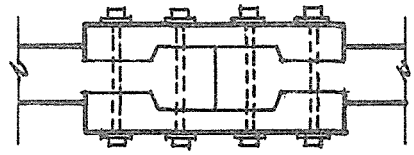
FISH PLATE JOINT



SCARF JOINT

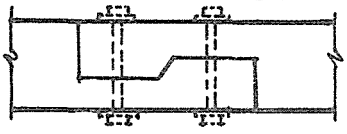


HALF LAP

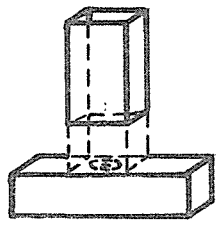


TABLED FISH JOINT

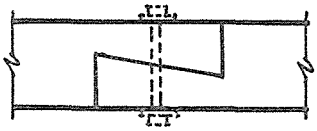
220 Yds.



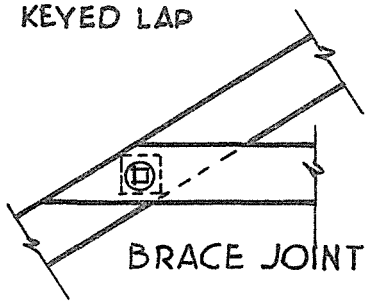
KEYED LAP



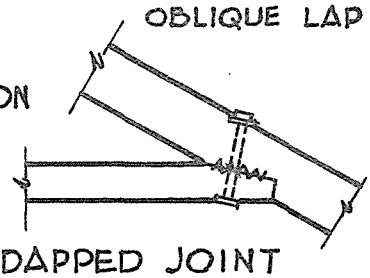
POST CONSTRUCTION



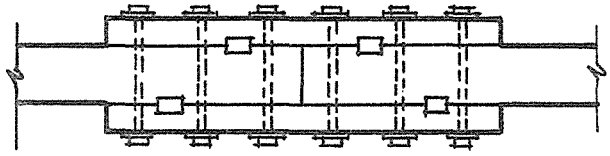
OBLIQUE LAP



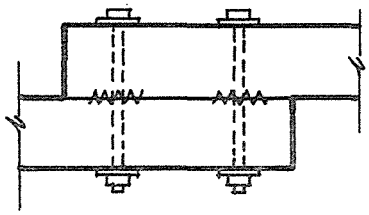
BRACE JOINT



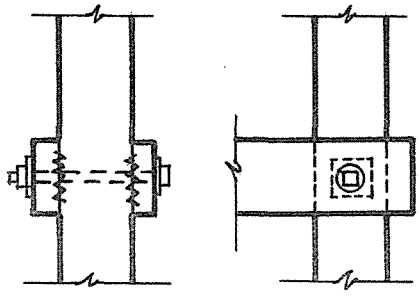
DAPPED JOINT



FISH JOINT KEYED AND TABLED

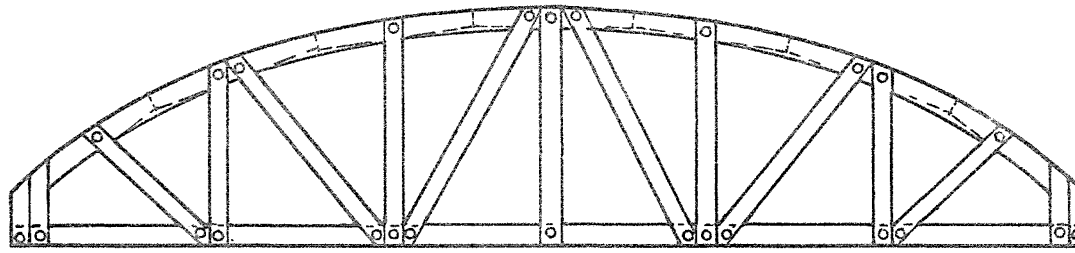


LAP JOINT

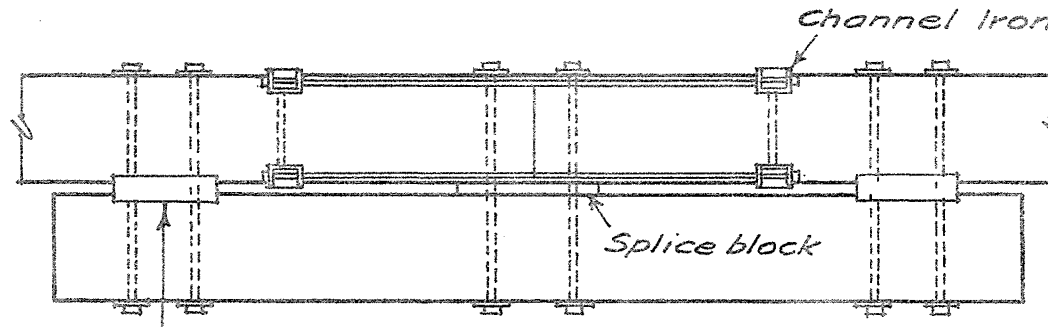


TIE JOINT

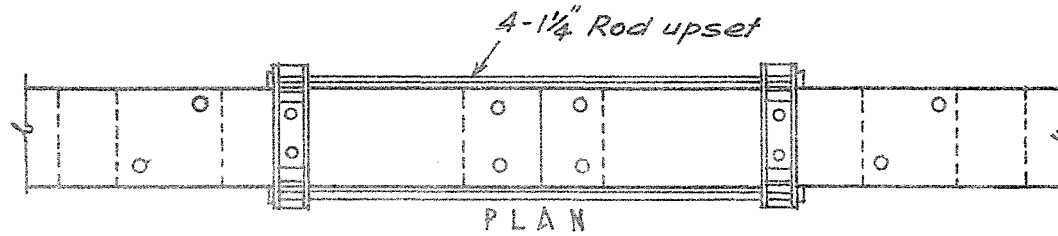
HEAVY JOINT DETAILS



ARCH CENTERING



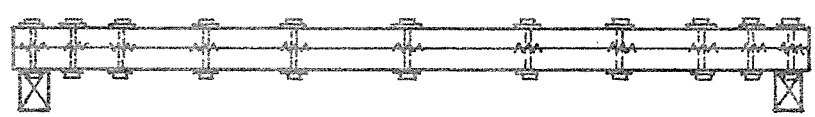
ELEVATION



PLAN

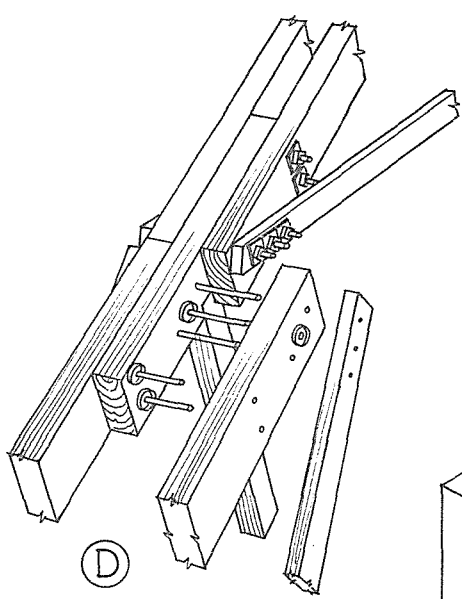
BOTTOM CHORD SPLICE

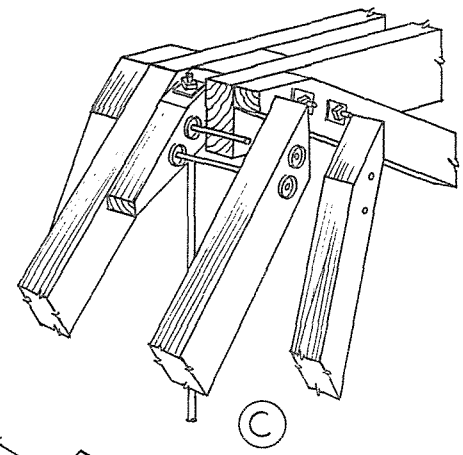
BRIDGE STRINGERS AND TIES

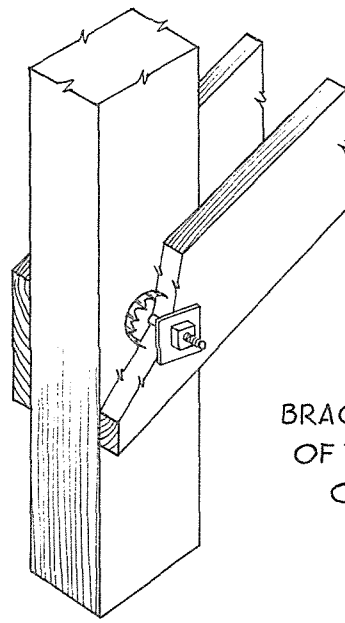


COMPOUND BEAM

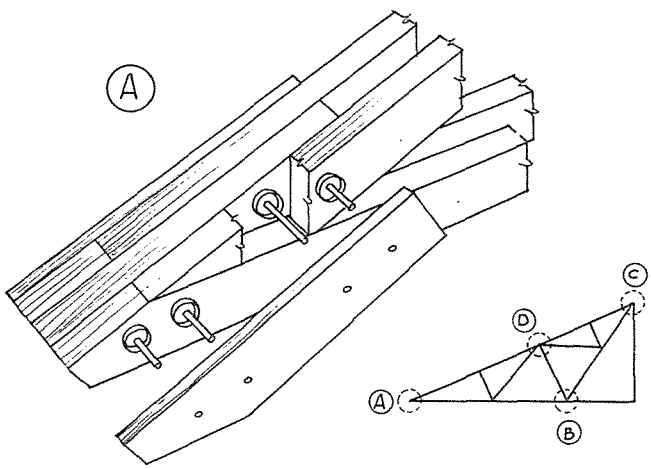
HEAVY JOINT DETAILS

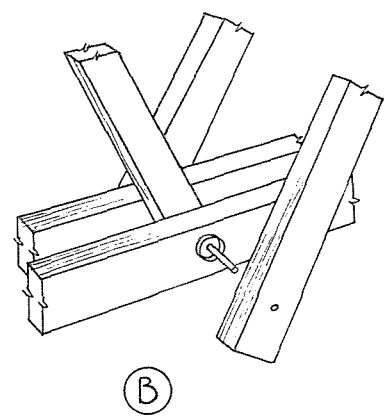






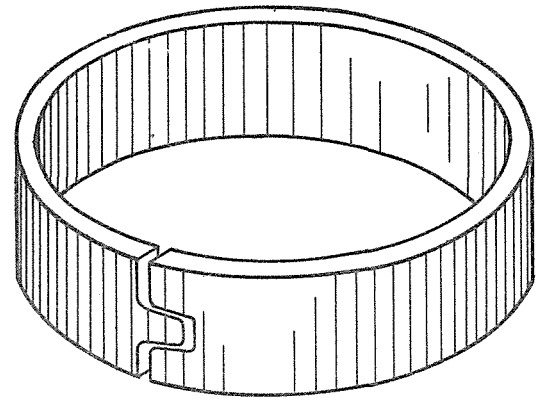
BRACE SHOWING USE
OF TOOTH RINGED
CONNECTOR



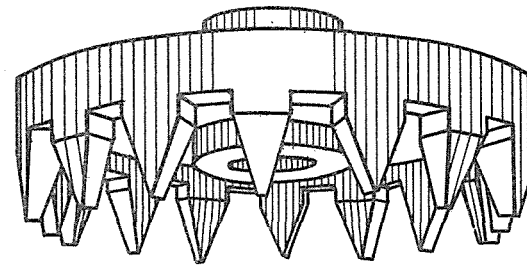


COURTESY OF TIMBER ENGINEERING CO., INC.

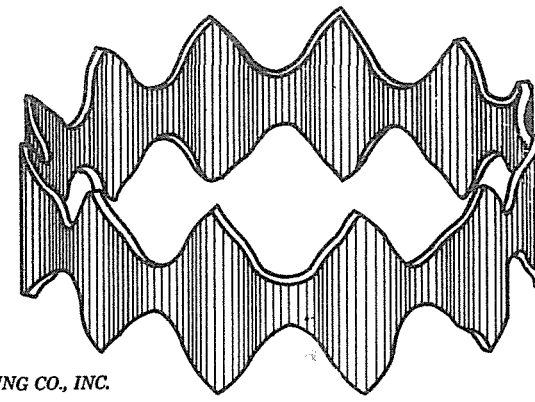
RING CONNECTOR DETAILS



A Split-Ring Connector is a smooth ring of steel with a tongue and grooved break or "split" which increases its load capacity. Split rings transmit loads when placed in pre-cut grooves in the faces of adjoining timbers.
Made in four sizes. 2½", 4", 6", 8", inside diameter.



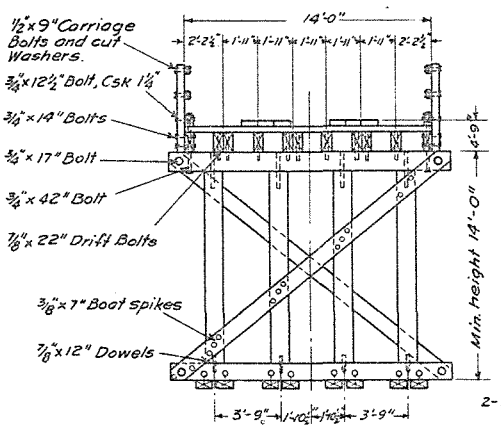
A Shear-Plate Connector is a circular, malleable cast iron plate with arranged about an annular rim on one face, to be imbedded in a pre-cut groove in the timber, and a boss on the opposite face to fit a hole in a steel trap or gusset plate. They transmit loads between wood and steel. Made in 3⅛" diameter only.



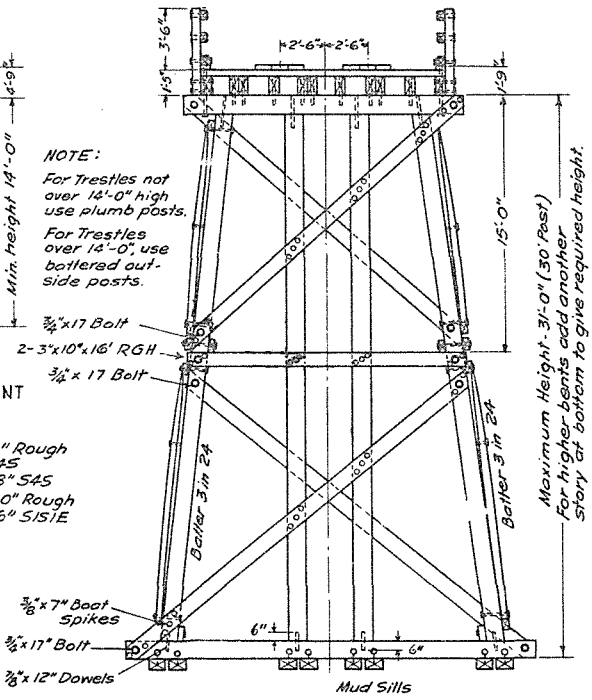
COURTESY OF
TIMBER ENGINEERING CO., INC.

A Toothed-Ring Connector is a ring of sixteen guage hot-rolled steel, ribbed to guard against lateral bending, with sharpened teeth on each edge. These rings, imbedded half their depth in the contacting surfaces of adjacent timbers, transmit loads from member to member.
Made in four sizes. 2", 2⅝", 3⅜" and 4" inside Dia.

RING CONNECTORS



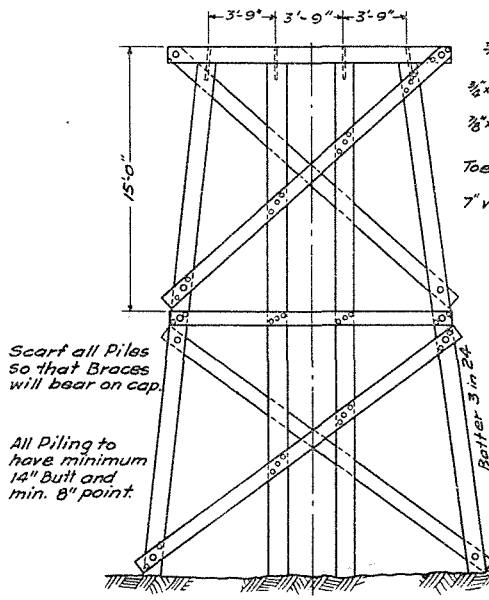
PLUMB POST AND FRAME BENT



BATTER POST FRAME BENT

MATERIAL:

Caps - 12"x12"x16'-0" SISIE
Posts - 12"x12" SISIE
Sills - 12"x12" SISIE
Stringers-6"x14" SISIE
Roadway Plank-4"x12" SISIE
Run Plank - 4"x10" Rough
Sway Bracing - 3"x10" Rough
Hand Rails - 3"x6" S4S
Hand Rail Posts-6"x8" S4S
Mud Sills - 6"x12"x3'-0" Rough
Guard Rail - 6"x6" SISIE

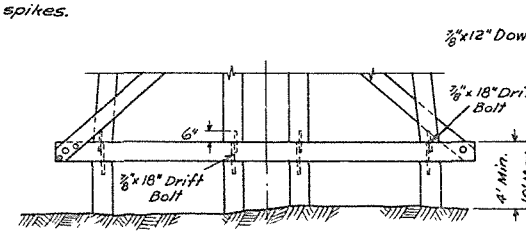


Scarf all Piles so that Braces will bear on cap.

All Piling to have minimum 14" Butt and min. 8" point.

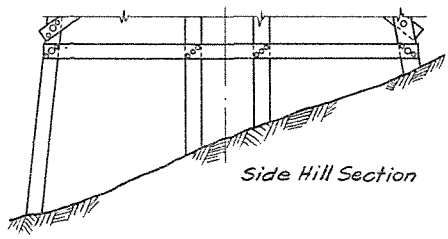
PILE BENT

Toe nail mud sills with 7" wire spikes.

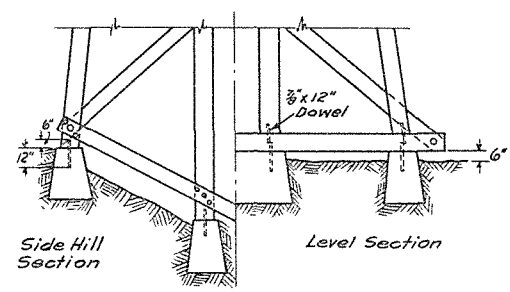


PILE FOOTINGS

Length of Bolts in Pile Bent to be determined from average size of piles available.



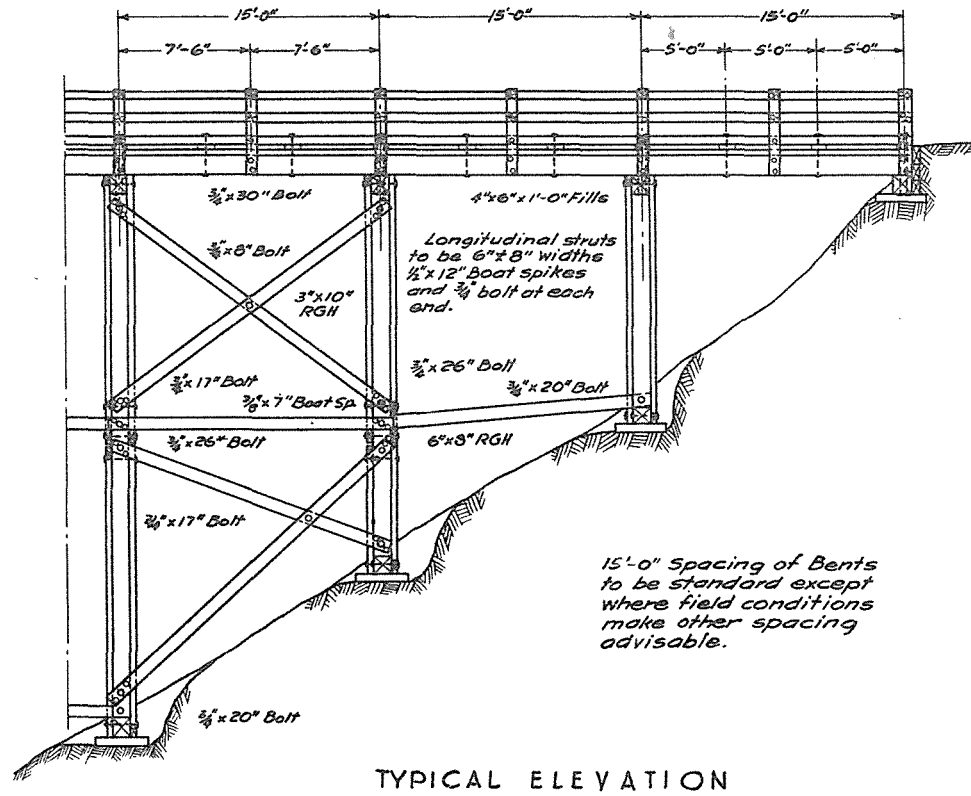
Side Hill Section



CONCRETE FOOTINGS

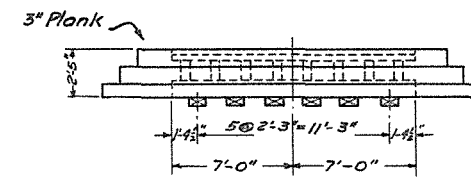
From "Standard Trestle", H-15 Loading-R6

TRESTLE DETAILS

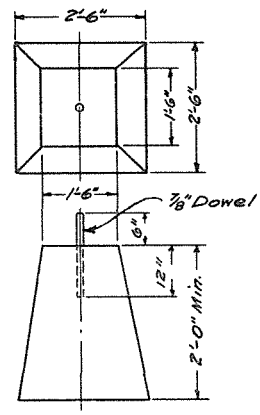


TYPICAL ELEVATION

From "Standard Trestle"
H-15 Loading
R-6



BULKHEAD DETAIL



CONCRETE FOOTING

GENERAL NOTES

Cedar Piling to be used when available. Minimum diameter of 8" point and 14" butt, maximum butt 18" diameter, to be straight and of live timber.

On Frame or Pile Trestles omit sway bracing for heights less than 6'-0" from ground or pedestal to top and bottom

Cover top caps, top of piles and top and bottom of posts with 30 lbs. Asphalt impregnated roofing felt, bent down to shed water.

All bolts to be ¾"ϕ with standard malleable washers.

All drift bolts and dowels to be ⅞"ϕ.

All holes to be bored 13/16" ϕ.

All Concrete to be 1:3:5 mix.

All timber to be structural grade Douglas Fir.

Cedar mud sills to be used if available.

TRESTLE DETAILS

Holes in treated timbers should be protected as discussed in Chapter VI. The life of a treated timber trestle is estimated to be at least 15 years. Details of trestle construction are shown on pages 170 and 171.

119. Precautions against fire.

All structures should be protected against the possibility of destruction by fire. Sole dependence should not be placed on the use of incombustible materials. These materials may not burn, but they may be so weakened by continued exposure to heat, that the building will eventually collapse. Good protection may be obtained by the use of a sprinkling system, so designed that continued application of heat above a certain temperature will cause the valves to open and a stream of water to flow over the exposed surface. All buildings must be constructed to meet the requirements of the National Board of Fire Underwriters and of the National Fire Protection Association.

Wooden bridges and trestles do not have to meet the above requirements, but they may be protected to some extent by the application of flat sheet metal strips over the caps and over the stringers directly under the flooring.

CHAPTER XII - SCAFFOLDS AND TOWERS

120. General.

Almost all building construction jobs require the use of scaffolds, and some jobs require the use of material hoisting towers. For this reason an entire chapter is devoted to discussions of the various types so that those employed in Forest Service construction work may be familiar with the subject.

The proper type should be used for each job. However, for the sake of safety it is much better to use a scaffold which is too heavy rather than one which is too light.

121. Scaffolds.

The most common types of scaffolds are described in this article. A scaffold must be safe. Judgment must be exercised in proportioning the different parts. A scaffold for the use of stone masons or bricklayers should be of heavier construction than a scaffold for the use of painters. The sizes and proportions given are those commonly employed for ordinary construction work. They may be increased or decreased to suit the conditions of a particular job.

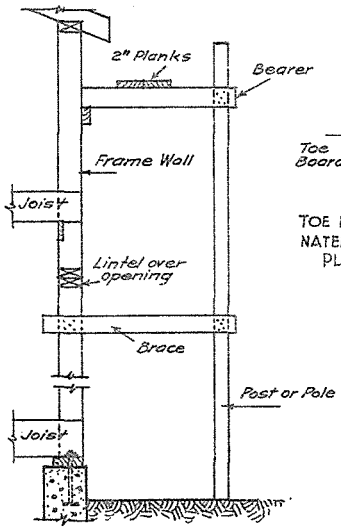
A. Two-post scaffold

The two-post scaffold is the type most commonly used for ordinary building construction, but is not usually used for buildings more than five stories high. It consists of two sets of upright posts, which support the working platform. The various parts which make up the two-post scaffold are described in detail below. An illustration is shown on page 174 .

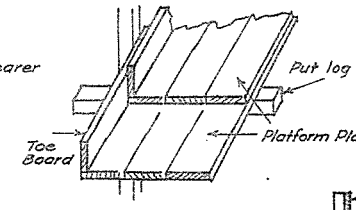
(a) Upright posts

In ordinary light construction work when the scaffolds are not high, the uprights may be of 3" x 4" material. For heavier work, where the scaffolds are higher, the posts should be of 4" x 4" or larger material. Spacing of the posts usually depends upon the lengths of the platform boards to be used. The common spacing is 10 feet, but this may be varied.

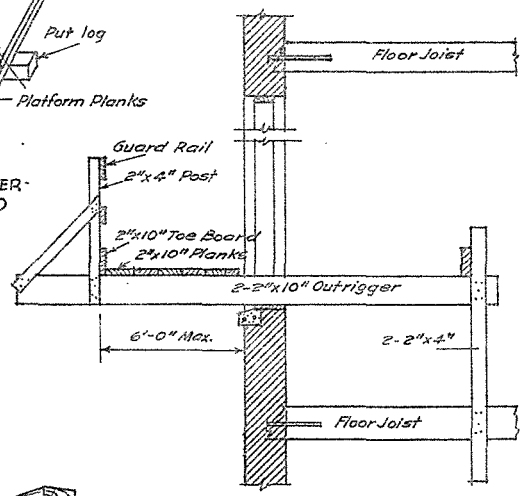
The posts should be placed far enough apart to allow for at least a five plank platform. This spacing will ordinarily be approximately 4 feet. When it is necessary to build a scaffold higher than the ordinary length of the uprights, they should be spliced by butting them against each other and using a board at least 4 feet long as a fish plate to connect them together. The material used in uprights should be of a good grade and reasonably free from knots. The strength of the entire scaffolding depends upon the strength of the uprights.



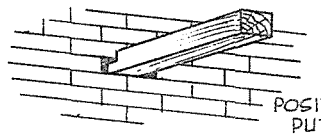
CARPENTERS SCAFFOLD



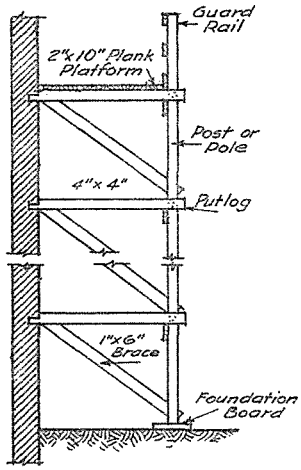
TOE BOARD RESTING ALTERNATELY ON PUTLOGS AND PLATFORM PLANKS

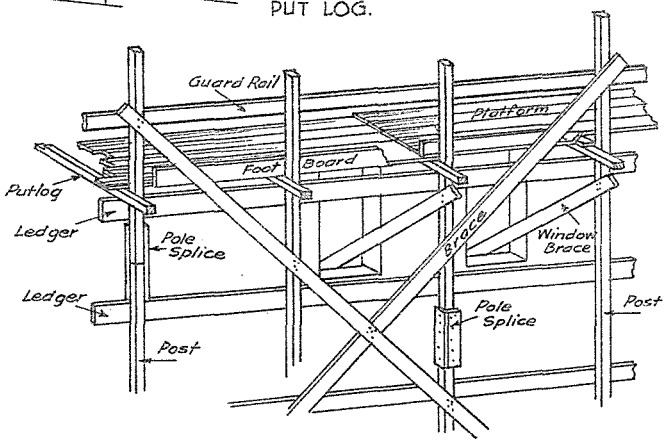


OUTRIGGER SCAFFOLD

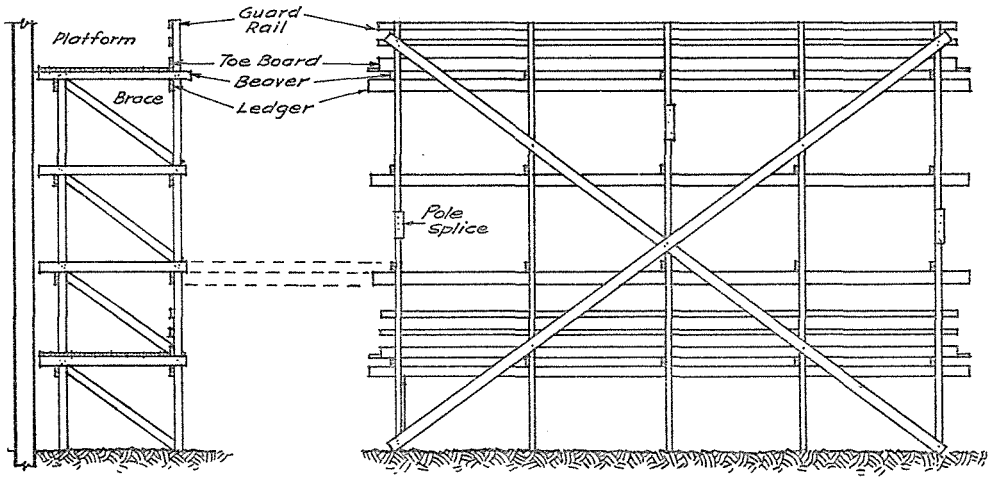


POSITION OF PUT LOG.



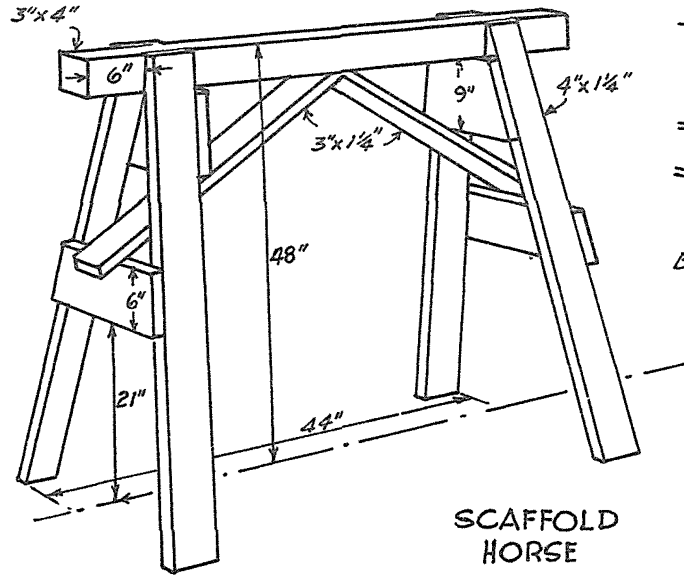


ONE POST SCAFFOLD

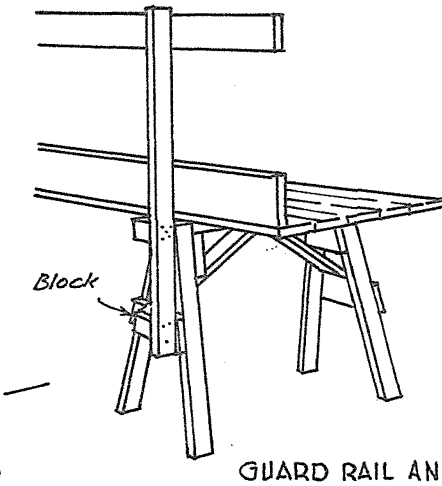


TWO POST SCAFFOLD

SCAFFOLDING

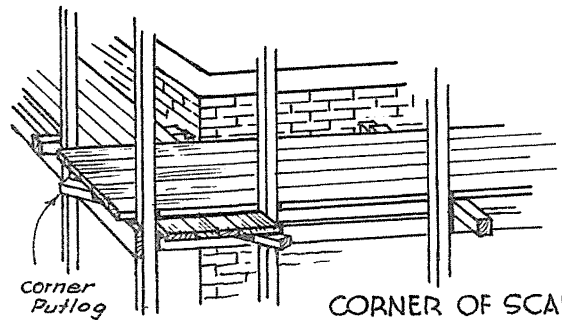


SCAFFOLD HORSE

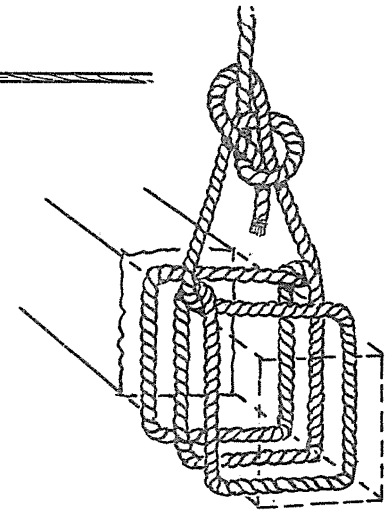


GUARD RAIL AND FOOTBOARD ON A SCAFFOLD HORSE.

METHOD OF LAYING PLANKS

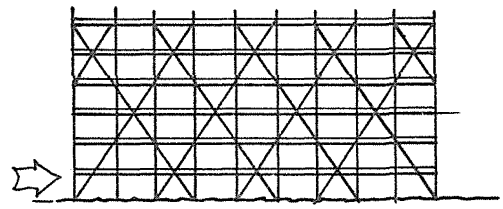


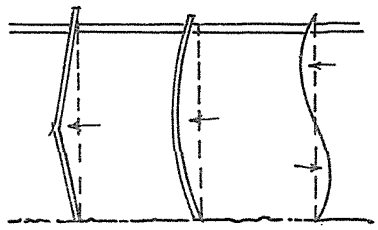
CORNER OF SCAFFOLD



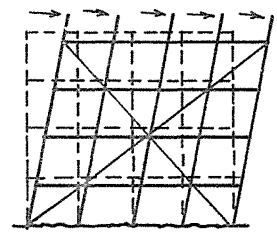
SCAFFOLD HITCH

LONGITUDINAL BRACING ON A SCAFFOLD

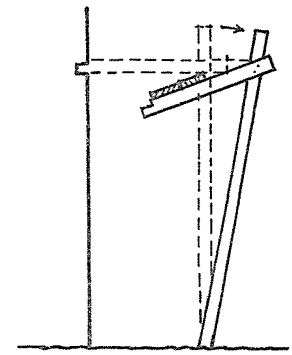




FAILURE BY BUCKLING OF POLES



COLLAPSE PARALLEL TO WALL



FAILURE BY FALLING AWAY FROM BUILDING

SCAFFOLDING

(b) Ledgers

Ledgers are horizontal stringers which connect between the uprights to provide stiffening against buckling. The most common practice is to use 1" x 4" or 1" x 6" boards for this purpose. The vertical spacing between ledgers is usually dependent upon the distance required between platforms, but should never be more than 40 times the least dimension of the upright posts. Ledgers should be placed on the inside of the posts to allow room for the horizontal bracing on the outside.

(c) Bearers

Bearers are cross pieces which are used chiefly to support the platform planks. They also serve to stiffen the upright posts in the direction opposite to the ledgers. Bearers are set edge-wise on the ledgers and are nailed to the upright posts. They are usually made longer than the width of the scaffolding to allow for the addition of an extra board between the scaffold and the wall. The size most commonly used is 2" x 4" or 1" x 6". Heavier construction may require larger sizes of bearers.

(d) Platform

Scaffold platforms usually consist of at least five boards which rest directly on the bearers. They should always be at least 2 inches thick because they must support considerable weight, especially if the uprights are spaced on 10 foot centers. Platform boards must be at least 2 feet longer than the upright spacing to allow for at least 1 foot overlap at each end. The planks should be laid close together. Most building codes do not require that the planks be secured to the bearers, but as a safety precaution, this should always be done. When a scaffold is built on two sides of a building, the platform planks should overlap, for the full width of the platform. Platform construction is illustrated on page 175.

(e) Cross Bracing

Cross bracing is necessary to prevent a scaffold from overturning or collapsing. It is usually used only on the outside of the scaffold because it would seriously interfere with the work if placed between the scaffold and the wall. The usual size of material used for cross bracing is 1" x 6", although for light work a 1" x 4" board may be used. If the scaffold is not tied to the wall in any way, transverse braces should be placed between the upright posts between platform levels. The usual size of material for transverse braces is 1" x 6".

B. One -Post Scaffold.

A one-post scaffold is similar to the two-post type, except that only one line of uprights is used. The wall is used to support the other side of the platform. It is preferred by most bricklayers, and is often called a "brick-masons' scaffold".

In the two-post scaffold the weight of the platform and the load upon it is borne by the bearers which are nailed directly to the uprights. In the one-post scaffold the platform and the load upon it is borne by the putlogs. One end of the putlog rests on the ledger without being nailed to it, and the other end rests on or in the wall.

The transverse bracing is different in the two types. The bracing perpendicular to the wall is necessarily omitted in the one-post scaffold because of the absence of the inner row of poles. Bracing in this direction consists almost entirely of ties to the building. The longitudinal bracing parallel to the wall is usually the same for both types.

An illustration of a one-post scaffold is shown on page 174 .

C. Carpenters' Scaffold.

The carpenters' scaffold is a combination of the two previously mentioned types. It is usually of lighter construction than either of them. Only one row of upright posts is used, but the platform rests on bearers rather than on putlogs. The bearer is connected on one end to the uprights and on the other end to the wall of the building. Ledgers are often omitted unless the scaffold is high. Cross bracing parallel to the wall is used to provide rigidity and strength. The platform is seldom more than three boards wide, but should consist of 2 inch material.

An illustration of a carpenters' scaffold is shown on page 174 .

C. Beam Scaffold.

The beam type of scaffold is commonly used by iron and steel workers, pipe fitters, and others, whose work may be conveniently done from platforms, supported from above. It consists essentially of a platform of 2 inch material which rests on 4" x 6" wooden beams. The beams are supported by ropes which hang from roof girders or trusses. The rope should be of a sufficiently large diameter to support the loads which are placed on it. Care should be taken in attaching the rope to the beams so that there will be no danger of the beams twisting or overturning. The hitch usually used for this purpose is illustrated on page 175 .

E. Outrigger Scaffold.

Outrigger scaffolds are often used in the construction of brick buildings when there is not sufficient room to provide a post scaffold on the outside. Outriggers usually consist of two pieces of 2" x 10" material, nailed solidly together. It must not extend more than 6 feet beyond the wall of the building and must be securely fastened on the inside by bracing to the floor beams. The 2 inch platform is securely nailed to the outriggers.

An illustration of this type of scaffold is shown on page 174 .

F. Horse Scaffold.

This type of scaffold is very convenient for the use of brick masons when the height of the building to be constructed is not more than 20 feet. Five-foot horses are constructed and placed perpendicularly to the wall, about 10 feet apart. A 2 inch platform is laid on top of the horses. Additional tiers are built by removing all but the outer row of platform planks, which are left to support the horses. Horse scaffolds should never be more than four tiers high.

An illustration of a horse scaffold is shown on page 175 .

G. Safety Scaffold.

This type of scaffold is widely used on large construction jobs. It consists of a platform which rests on steel putlogs and is supported by steel cables from a steel outrigger beam. The outrigger beams are firmly anchored to roof beams or intermediate floor beams. The platform is raised and lowered by hoisting drums which are connected to the putlogs and around which the steel cable is wound. There will be very few times when the use of this type of scaffold will be economical for Forest Service Construction.

122. Material Hoisting Towers.

Although the use of a tower for hoisting materials will seldom be required for Forest Service work, a brief description of their construction and use will be given.

Material hoists are convenient for raising all materials used in the construction of a building. The tower which encloses the hoist should be built opposite a vertical row of windows so that the building material may be conveniently unloaded at the point where it is most needed. Towers are usually built of 4" x 4" corner posts, which rest directly on large sills placed on a plank foundation. The posts are made rigid by cross bracing and horizontal braces placed approximately 6 feet apart vertically on all four sides of the tower. Towers should be solidly guyed to prevent overturning. If the use of guys is impractical, the tower must be securely fastened to the building at short intervals.

The hoist platform should be sufficiently large to accomodate the amount of material which may be used between trips of the elevator. The hoist is raised and lowered by a rope or wire cable. The cable is attached to the top of the hoist and passes through a sheave at the top of the tower and then down to a hoisting drum on the ground. On small construction jobs the hoisting drum may be operated by hand, provided the material platform is not too large. On larger jobs the raising and lowering is done by mechanical means.

CHAPTER XIII - LOG CONSTRUCTION

123. Logs - Selection and Handling

The selection of straight, smooth, even-sized logs is the prime consideration in starting the erection of a log building. Top diameters should be as uniform as possible, not less than 8" or more than 12". Taper should be as small as possible. Logs longer than 40 feet may require a smaller top diameter in order to keep down excessive diameter at the butt.

Logs should be cut in late fall or winter. Logs cut in spring or summer peel easier but check to an undesirable degree while seasoning. Insect activity is dormant during the winter months and logs cut and seasoned during that time are less liable to insect or rot fungus attack and damage. Logs should be cut, peeled and piled on skids well above the ground to season for at least six months before they are put into a building. All knots, limbs, or bumps should be trimmed off carefully at the time the log is peeled. A narrow strip or score should be cut on opposite sides of the log for its entire length to increase the adhesion of the bark, if its retention is desired. The logs should be single decked, with 2" or 3" between logs. Each log should have the sweep or curve laid so that its weight will tend to straighten it while drying. If skidding room is limited, the logs may be double decked but should have poles placed between each tier of logs. Unrestricted air circulation will materially aid the seasoning. The most desirable timbers to use are cedar, pine, Douglas fir, tamarack, larch, balsam and hemlock, in the order named. Many hardwoods are also suitable because of small taper, narrow sap ring and durability. Logs should be cut at least 2 feet longer than actually needed so that they can be trimmed evenly after they are in the building.

Logs should be carefully sorted before construction starts so that the best logs can be used in the front and the more conspicuous sides of the building. If the logs are not even in size, the larger logs should be at the bottom of the wall.

The dimensions of a log building are the inside measurements from log to log. The outside dimensions will vary with the size of the logs, hence the use of inside measurements. Logs should be cut at least 6 feet longer than the inside dimensions of the building. In erecting a log structure the logs in the wall must be kept even or plumb on the inside because of the difficulty of building if the log walls are not straight. Logs will not be hewed on the inside.

Logs may be scribed and grooved by the Scandinavian method if the building is to be used all of the time. This will be described in detail later. Log buildings for summer use only, or other structures, such as barns, woodsheds, etc., should not be scribed and

grooved. When logs are not scribed, they should be fitted as close as possible to keep the crack between the logs at a minimum.

124. Corner Construction

The corner is the most important item of log construction, and the appearance and stability of the structure is principally dependent upon it. Several different types of corner construction are in use, and each of them has several variations due to local custom or individual ideas.

A. Round Notch or Saddle Corner

The round notch or saddle corner is considered most satisfactory from every standpoint for Forest Service use. This corner is selected for the standard for several reasons:

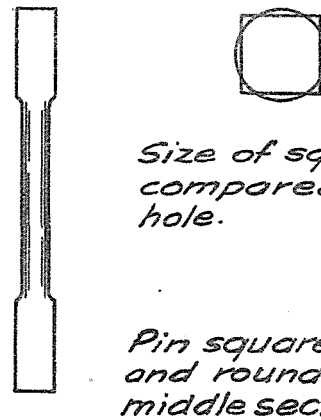
(a) Appearance - It gives the most distinctive appearance as a log corner, since the logs project beyond the corner and do not appear dubbed off as is the case with some other corners.

(b) Stability - It is a good mechanical joint because it is self-locking and the logs are immovable. It is relatively simple to construct.

(c) Permanence - Since the material is all taken out of the under side of the upper log and the surface of the upper side of the bottom log is not disturbed, all moisture drains out of the corner and the wood is much less subject to decay because of moisture conditions.

The tools necessary to construct this type of corner are: A pair of log dogs, to hold the log in place; a pair of 12" wing dividers with pencil holding attachment; a sharp axe; a 2" gouge c chisel with outside bevel; and a cross-cut saw. The various steps in framing the round notch or saddle corner are shown on Pages 182 and 183 .

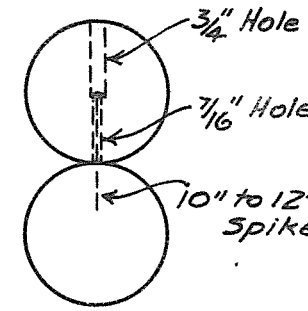
The two side logs are laid on the foundation and set in place. A face of two to three inches should be hewed on the under side of the bottom logs to make them lay flat. The two end logs are then placed and accurately centered so that the distance between their inside edges is the exact dimensions of the building. They should be dogged so that they will not move while being marked for the corner notch. The wing divider is set for one-half the diameter of the side log. With one leg of the divider resting upon the side of the under log and the other leg resting against the bottom of the upper log and directly above the lower log, both points of the divider are



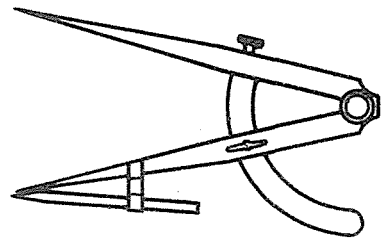
Size of square pin compared to round hole.

Pin squared at ends and rounded in middle section.

Seasoned D Fir preferred.

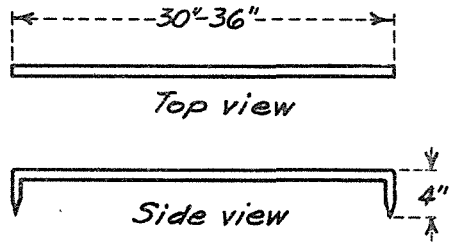


Bore 3/4" Hole 1/2 way through top log, then bore 7/16" hole through remainder of log. Then drive a 10"x 12" spike down as shown. Wall can then settle without interference from spike.

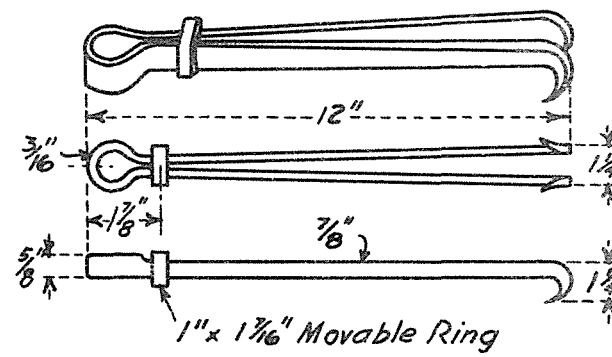


DIVIDER

2" GOUGE CHISEL



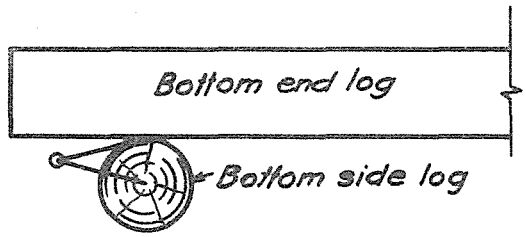
1/2" IRON DOG



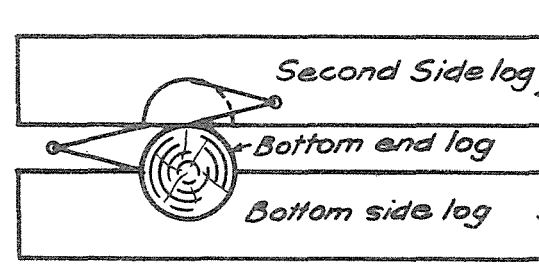
Forge ring and put on before bending end up.

NORWEGIAN LOG SCRIBE

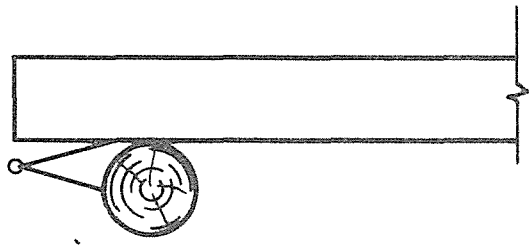
TOOLS FOR LOG CONSTRUCTION



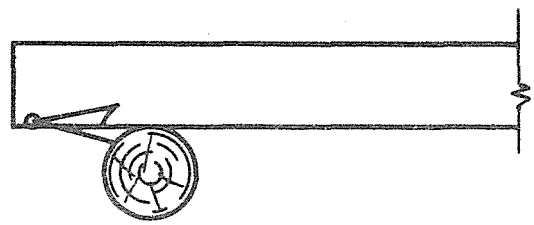
Take half of lower log diameter



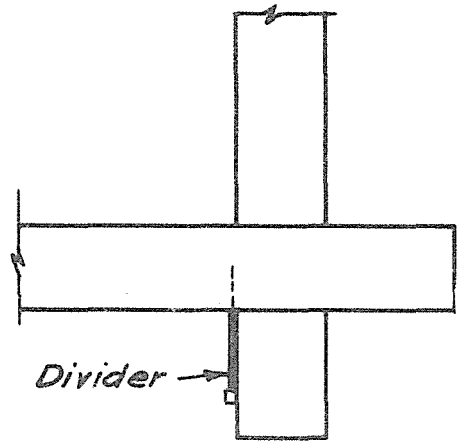
Take depth of space between side logs, then work as before.



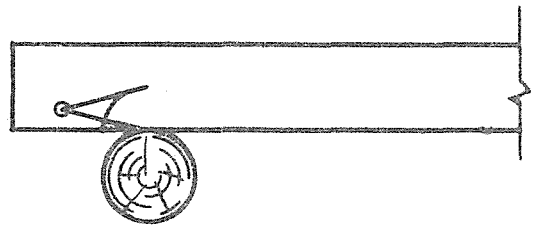
Begin on bottom of upper log



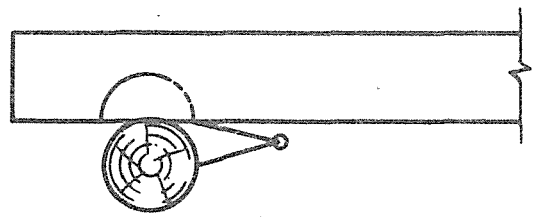
Move divider upward in circular motion.



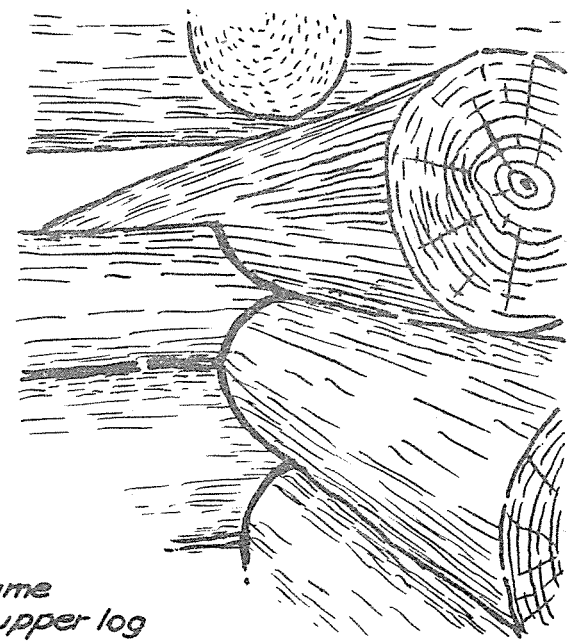
Divider is held parallel to the under log. You should stand facing side of log to be marked so as to keep points of divider lined up perpendicular to each other.



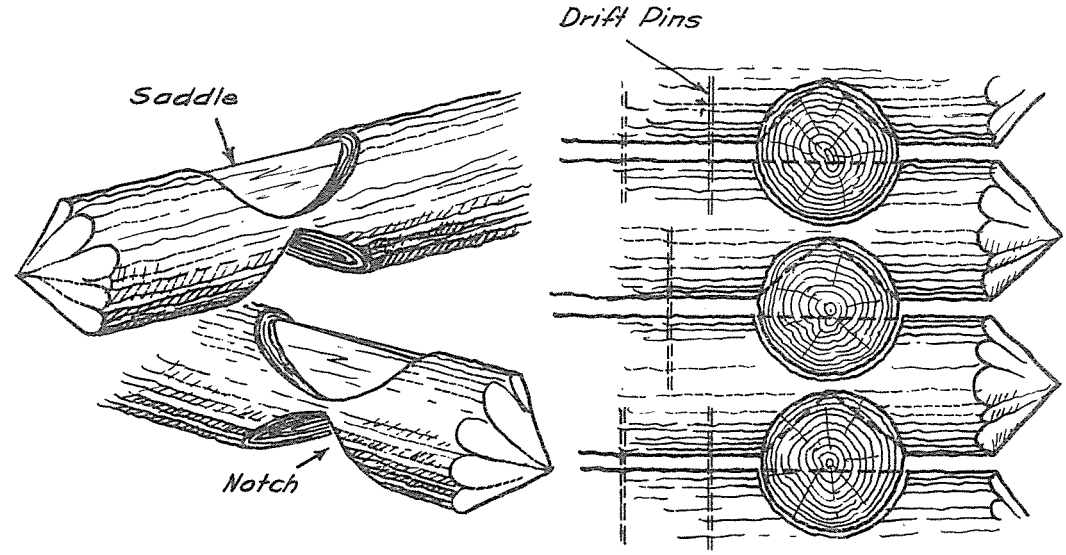
Top or quarter circle.



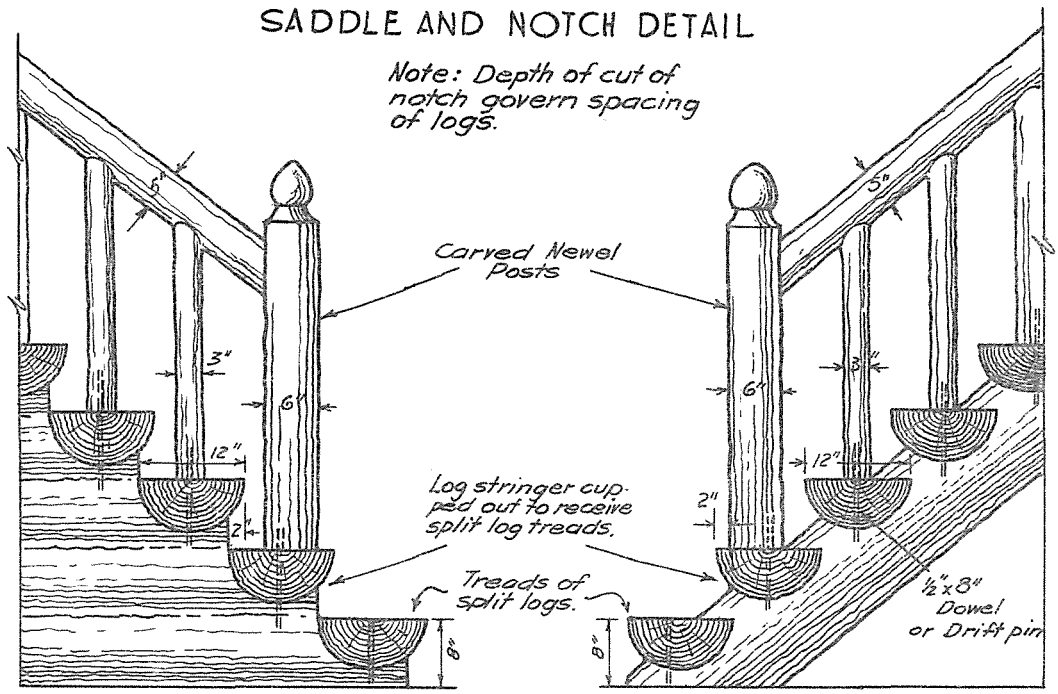
Move to opposite side of under log and repeat. Then repeat same operation on opposite side of upper log



SADDLE CORNER



SADDLE AND NOTCH DETAIL



STAIRWAY DETAILS

LOG CONSTRUCTION

moved in an upward direction so that the lower leg follows the curvature of the under log and the upper leg makes a mark on the surface of the upper log. This will be the intersection of the surfaces of the two logs when the notch has been cut from the upper log. This operation is repeated four times, to mark all four sides of the corner. A little practice soon makes a person adept at keeping the points of the divider perpendicular to each other at all times while making these marks.

After both ends of the log have been marked, it is turned over on its back. The divider scratch should be traced with an indelible pencil so that the mark for the notch can be more easily seen. The notch is chopped out roughly with the axe and chipped down close to the mark. The gouge chisel is then used to give it the finishing touches. The notch should be cupped out just enough so that the weight of the log will come on the outside edges of the notch, thus assuring a tight joint.

When the next side log is rolled into place, the dividers should be set apart the width of the space between the top of the first side log and the bottom of the next side log, and the marking should be done as before.

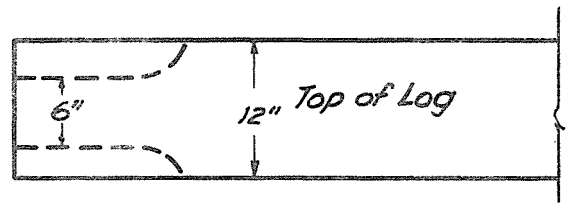
If it is desired to have the upper log "ride" the lower log a little to provide an especially tight joint between the two logs, the dividers should be set a little wider than necessary. This should also be done if the logs are to be scribed and grooved. Sufficient additional depth should be given the notch so that the log can be scribed for the groove.

B. Dovetail or Box Corner

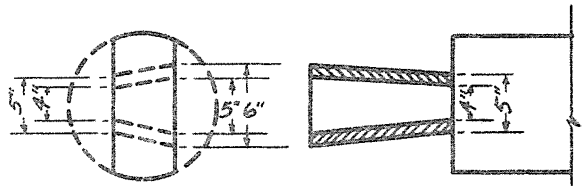
This is a strong corner and a good mechanical job can be made of it. All axe work must be done carefully to secure a neat job. This type of corner has the undesirable feature, however, that the logs are apt to open up a wider crack because it is framed from the part of the log where the least shrinkage occurs. The wood has a tendency to gather and retain moisture because of the logs being hewed down as they are to form the corner. This corner construction detracts from the "loggy" appearance desirable in log structures. Practical methods of marking and framing this type of corner are illustrated on Page 185.

C. Flat or Plain Tenon Corner

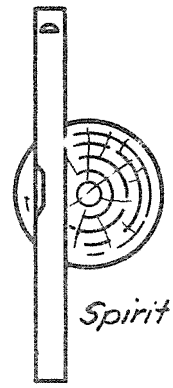
This corner is commonly used, and is made in two forms. In one, only the bearing surfaces are framed, while in the other all four sides of the tenon are framed flat. It has the undesirable feature that it is not self-locking. It is simple and easy to make, and most economical for temporary structures. The logs should be pinned as illustrated on Page 186. All framing can be done on the ground before the log is put on the building. A neat-looking job can be secured if care is used in framing.



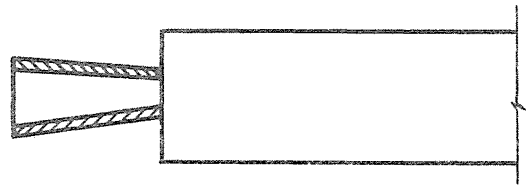
Hew flat at dotted line

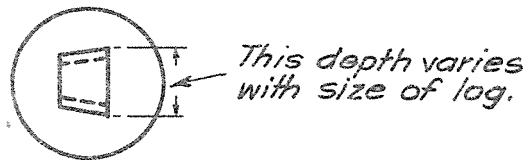


Mark as shown and cut to dotted lines. Note that bearing surface of tenon has a two way bevel so that logs are locked in place.

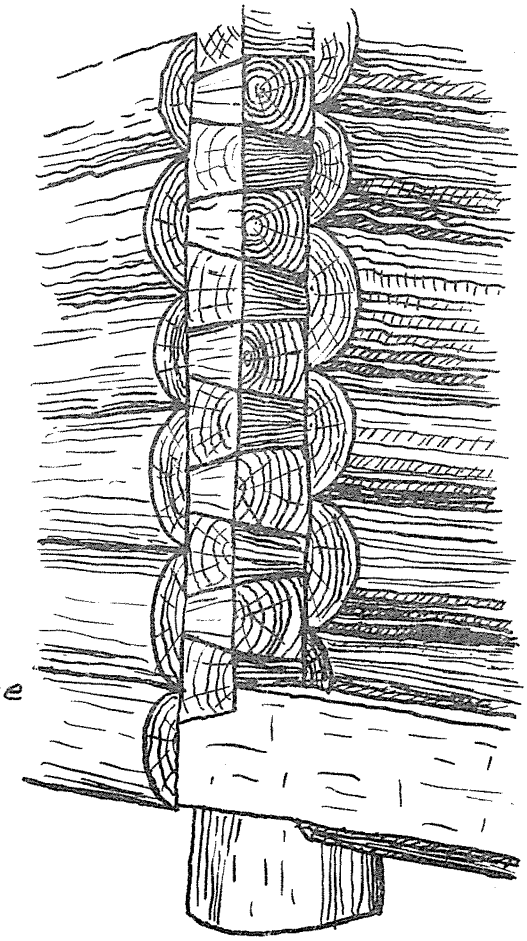


Log is dogged in place, then use spirit Level to mark end cuts at start.

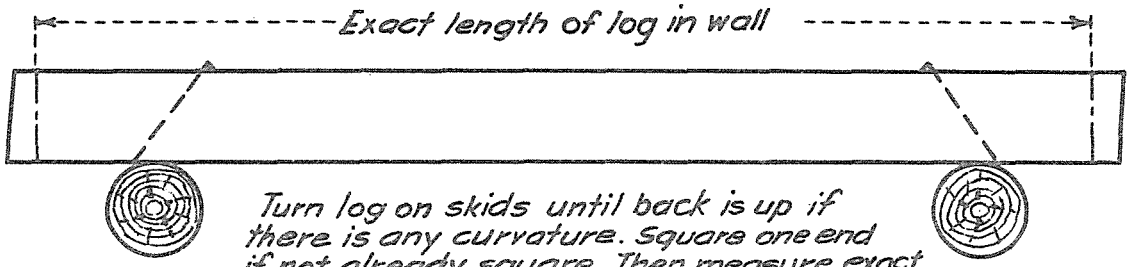




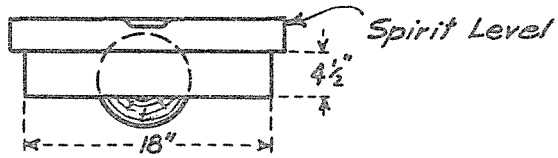
The dimensions of cuts given are indicative only. The depth or thickness of the tenon varies with the size of the log and the bottom may be deeper than the top cut or vice-versa. The tenon is not always in the center of the log.



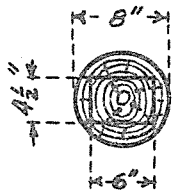
DOVETAIL CORNER



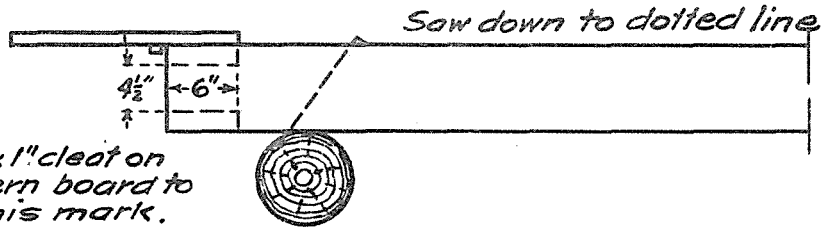
Turn log on skids until back is up if there is any curvature. Square one end if not already square. Then measure exact length of log and saw opposite end square.



Having determined the average thickness of the "tenons" from the average top and butt diameter of the logs, prepare a piece of board about 18" long and the same width as the tenons are thick. Drive a nail through the center of the board and into the center of the log. Now put the level on top of the board. Move the board until it is perfectly level, and then mark a line on the log at the top and bottom edge of the board. For 16" logs, 8" or 10" the board should be about 4½" wide.



Having marked the top and bottom of the tenon cut, now mark the sides. Use the plumb side of the level or a square to do this. The width of the tenon will depend on the logs. For 8" to 10" logs, 6" to 7" will work out.



Nail a 1"x1" cleat on the pattern board to make this mark.

Make saw cuts on each end, then cut chip off and smooth up surface again. Turn log over and do other side. Then frame out the sides of the tenon and the log is ready to go on the wall. Some fitting between corners will undoubtedly be necessary, but if logs are fairly straight and smooth very little should be needed.

FLAT CORNER

D. Upright or Groove-and-Tenon Corner

This corner has several very desirable mechanical features. Its rigidity depends upon the fastening of the corner posts to caps and bottom logs. It is not so stable for large construction but is excellent for wall rectangles which are unbraced. The weight of the building roof is not carried on the upright corner logs as in other types of construction, but rests on the wall logs which are free to settle uniformly. This makes a tight wall at all times, because the cracks will never open up. It is not a difficult corner to construct, although it calls for considerable skill and accuracy. A good mechanic can frame the complete building on the ground before any logs are placed on the foundation, and it can then be erected in a very short time. The method of framing is shown on Page 188. Door and window joints should be framed just the same as the corner logs except that only one side is grooved and the door side is left smooth or rabbeted out as may be desired. If logs are reasonably dry, from 3" to 4" should be left at each corner for settling. In about six months, the cap log will come down that much.

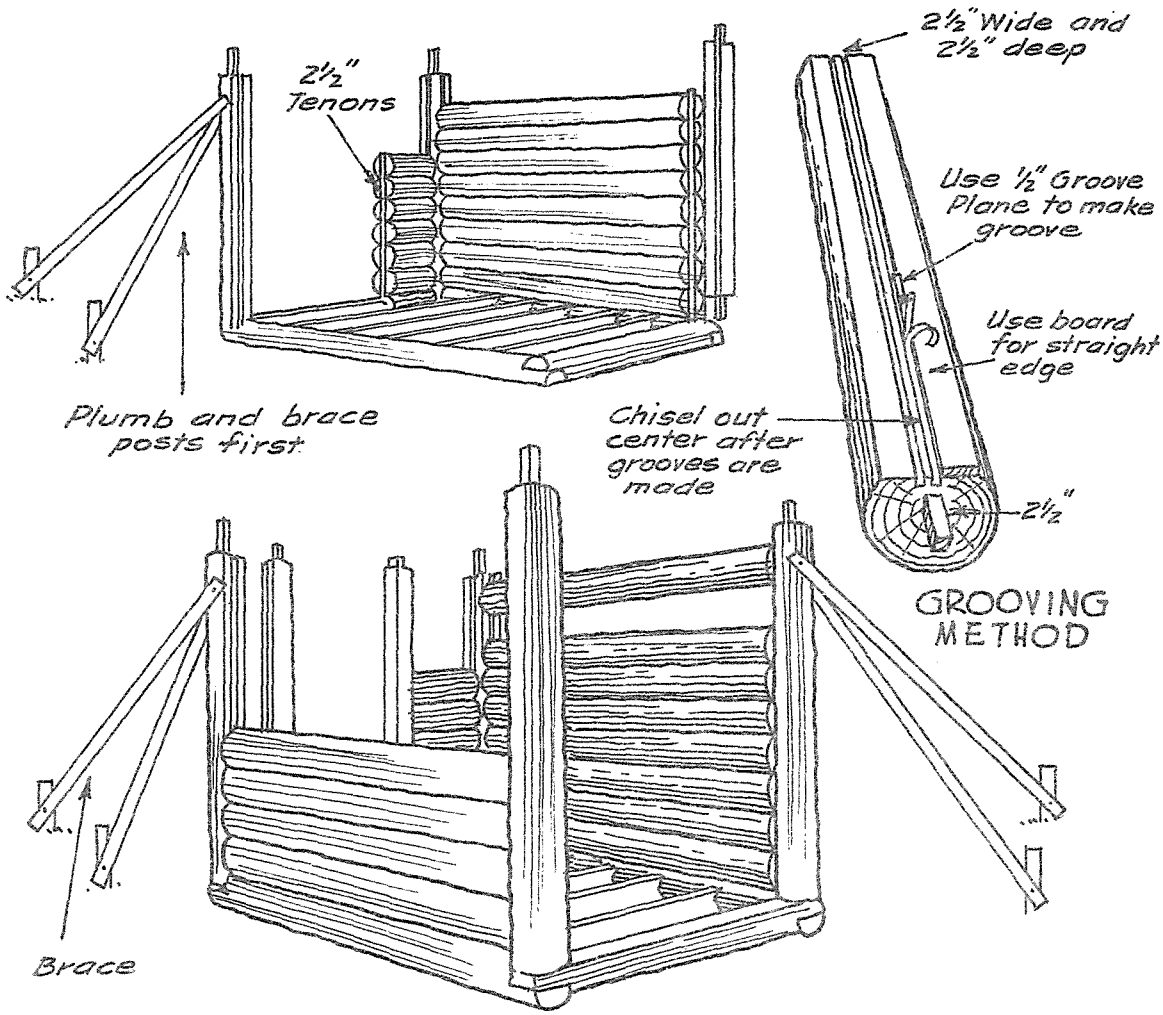
125. Floor Joists

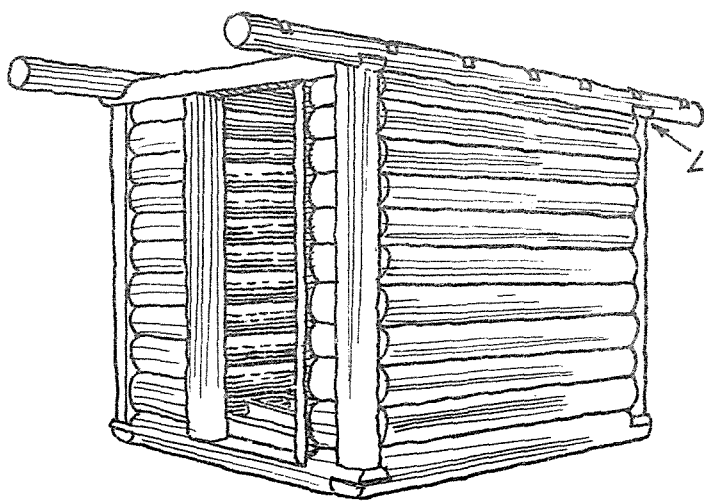
The floor joists should be put in place in a log building as soon as the first round of logs has been laid. They should be notched into the first side log and securely nailed in place. If the building has a concrete foundation, they can be set on top of the foundation as in a frame building. In order to give the ends of the joist sufficient bearing on the wall, it will be necessary to either notch the end into the side log or else hew it off on the inside. The simplest way is to cut out the notches before the log is rolled into place. Pole joists should be 4" to 6" in size and hewed straight on the upper side to provide level bearing for flooring. A number of ways of framing floor joists are illustrated on Pages 189 and 190.

126. Wall Logs

Several details must be watched while laying up the successive rounds of logs in the wall. The corners should be kept nearly level with each round. This can be determined by measuring up from the level of the floor joist from time to time. A variation of an inch in height will not cause any difficulty. The main idea is to come out level at the top log. The height of the corners is regulated in two ways; by increasing or decreasing the thickness of the tenon of the logs at the corner, or by reversing the top and butt ends of the logs in the wall.

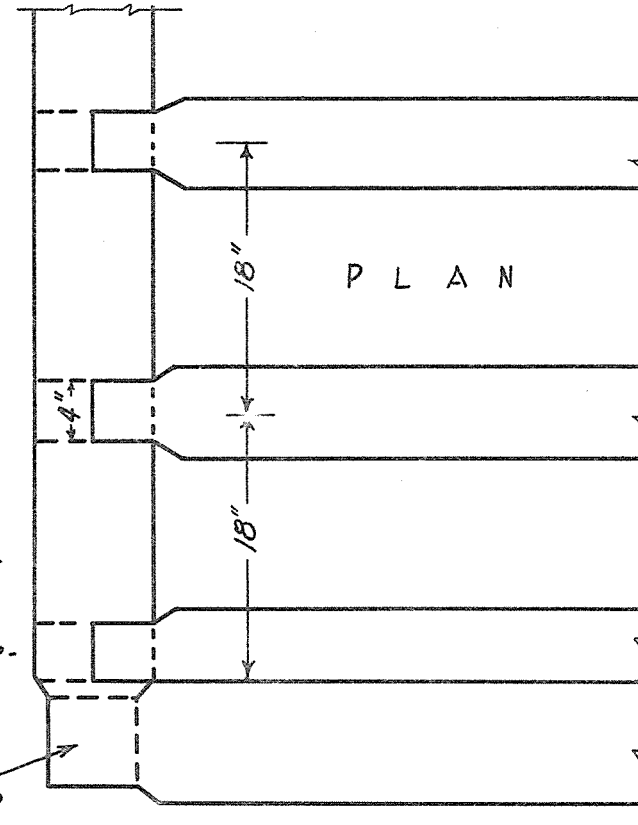
The inside face of the log wall must be kept plumb. A spirit level is sometimes used for plumbing the wall, but after the first two or three logs are up, a plumb board is much more accurate because of its greater length.





TONGUE AND GROOVE CORNER

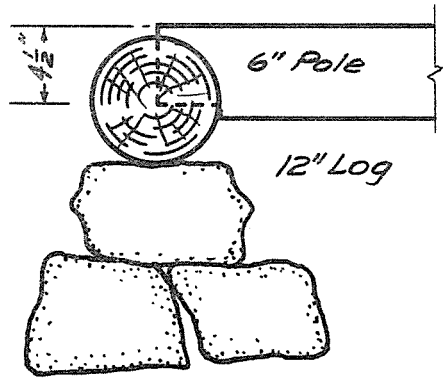
FRAMING POLES FOR LOG JOISTS



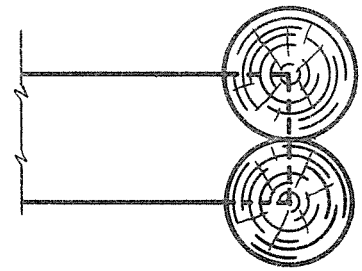
Make two saw cuts across log. Then chisel out half-way to make gain for end of joint. If it is undesireable to show saw cuts, use chisel to cut out mortise.

Half-Lap Joint

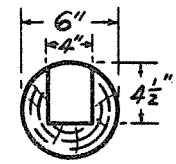
JOISTS NOTCHED IN



END

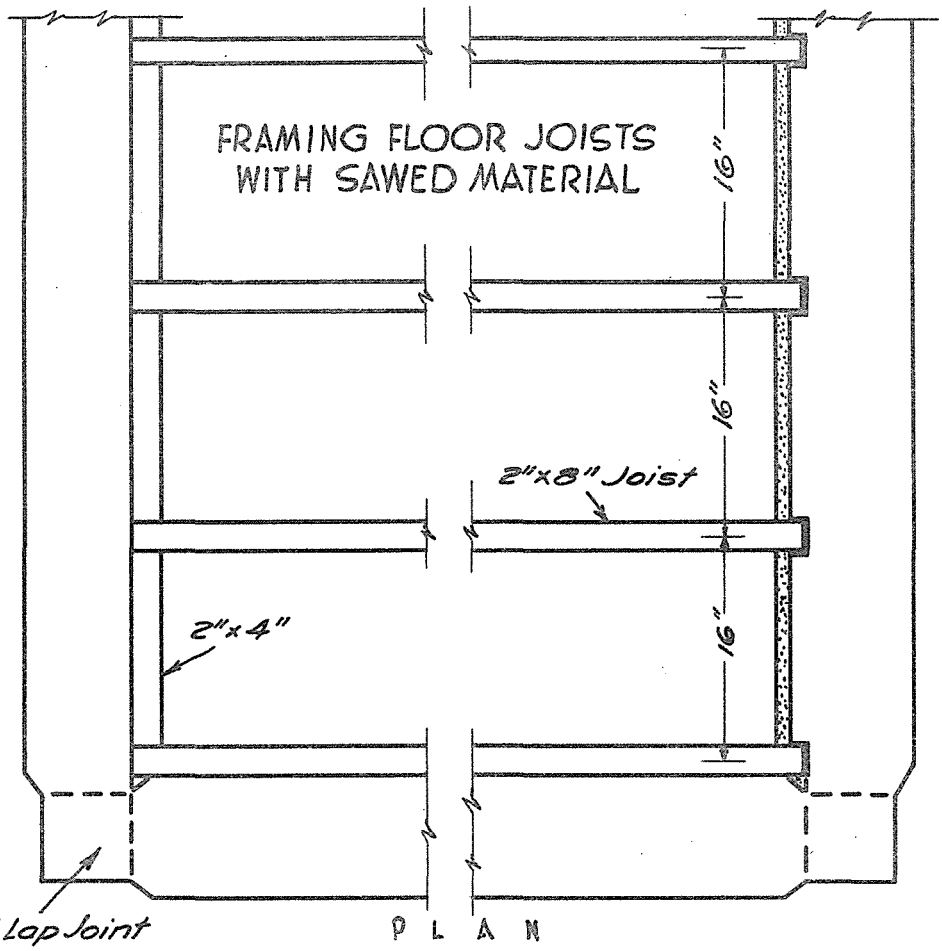


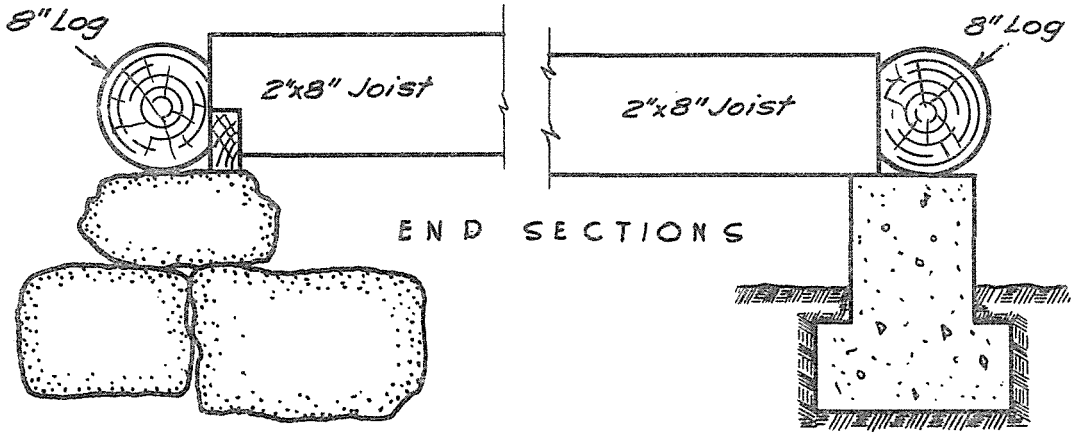
Tops of floor joists should be as much below top first and log as possible.



Frame Pole joists to same thickness at each other.

LOG FLOOR JOIST





Rock piers at corners and Center Bearing.

Hew sill log flat on inside face and spike 2"x4" to the log as bearing for the joist.

When concrete wall is used, joist may rest on wall. Saw notches on inside face of Sill Log.

SAWED FLOOR JOIST

The logs should be fastened together with wooden pins or large spikes. The spike method is the most simple, and is just as satisfactory as the wooden pin method. Pinning may be eliminated on small structures where alignment of the walls is not so important. On larger buildings it is essential, in order to maintain the logs in alignment and to prevent individual logs from springing out of place in the wall. The logs should be pinned on each side of an opening and about two feet back from each corner.

Logs which have a decided curve or sweep should be put in the wall with the bow or back up. They may be straightened out by making saw cuts near the center of the curve on the under side of the crooked log.

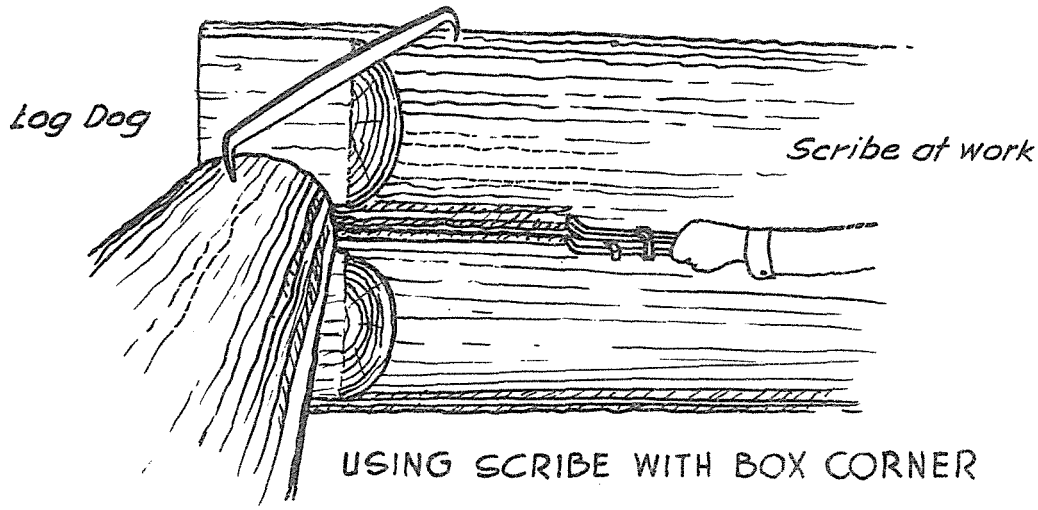
127. Chinkless Log Cabin Construction

This method of construction is used almost exclusively in the building of log structures in Scandinavian countries. It eliminates the chinking and mudding which are so prevalent in log buildings in the United States. It consists of grooving the under side of each log in each tier or round so that it saddles the log beneath making a close joint for its entire length. The marking of the groove is accomplished by the use of a tool called a cabin scribe or drag.

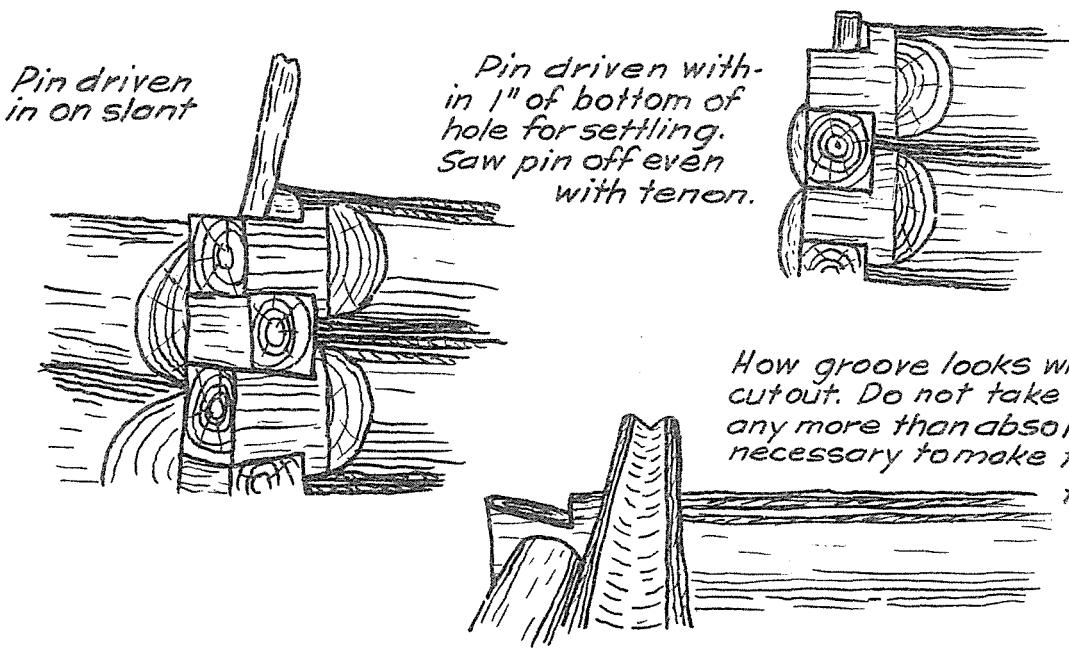
The scribe is a tool about 12" in length, made preferably of 3/8" square steel or iron bent in much the same manner as the spring in a steel trap. The two ends are turned down in two fingers about 1-1/4" and sharpened with a flat surface on the inside of the point toward the loop. These points should diverge to be about 3/4" at the points. The loop should be hammered out thin to provide spring so that the points may be easily spread or closed. A ring is welded around the two halves of the tool, which, when slipped up or down, fixes the adjustment of the points and prevents further spreading while the tool is being used. A chain link will serve the same purpose if it is slipped over the legs before the points are turned. A chip or any small piece of wood may be forced between the points to keep them from springing together.

The log to be fitted is framed at the ends and fitted down to within about 2" of the lower log at the widest crack. A good job of scribing cannot be accomplished if logs are too close. The scribe is adjusted at the widest space between them so that when held the tool is parallel to the interstice, the lower point of the scribe will ride on the surface of the lower log and the upper point will scratch the upper log. The upper log is marked in this manner on both sides of the wall. The tenon on the corners is also marked with the scribe set as described. The log is then turned over, the tenons worked down and a V-shaped groove cut in the remaining portion of the log, between the scribed lines.

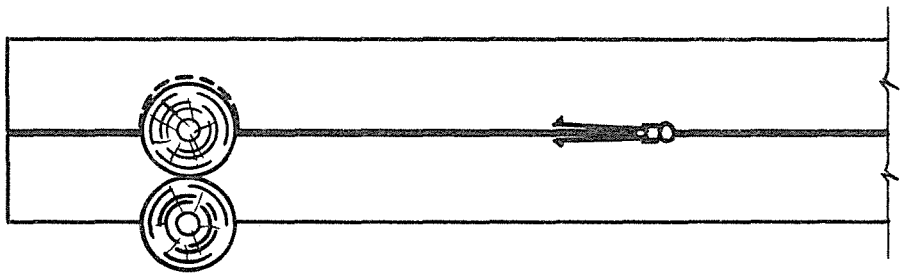
The V-shaped groove should be cut deep enough in the center to permit the outer edge of the groove to rest on the lower log. The least possible amount of material should be cut out, because the smaller the groove the better chance to obtain a close fit.



USING SCRIBE WITH BOX CORNER


Pin driven in on slant
Pin driven within 1" of bottom of hole for settling. Saw pin off even with tenon.
How groove looks when cut out. Do not take out any more than absolutely necessary to make tight fit.

USING SCRIBE WITH ROUND NOTCH



Mark and cut out notch as for ordinary wall. Then dog log into place and scribe making additional mark as shown by dotted line to deepen notch.

USE OF SCRIBE

An ordinary axe is used for cutting the groove. The principle of the scribe is based on parallel lines and it can be readily seen that if there is a hump on the lower log there will be a gouge in the upper one.

Where an airtight wall is desired, a strip of plumber's rolled oakum should be laid on the bottom log before the upper log is dropped into place. Dry moss also makes a good filler for this purpose.

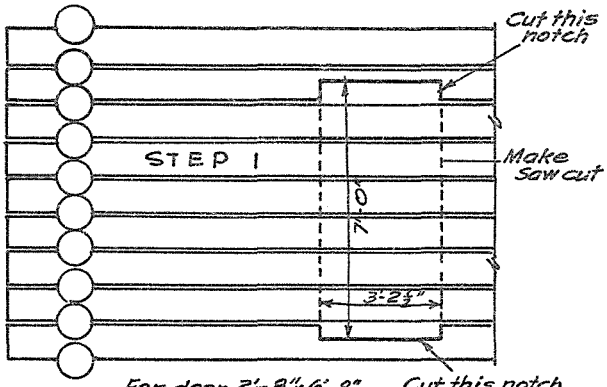
128. Door and Window Openings

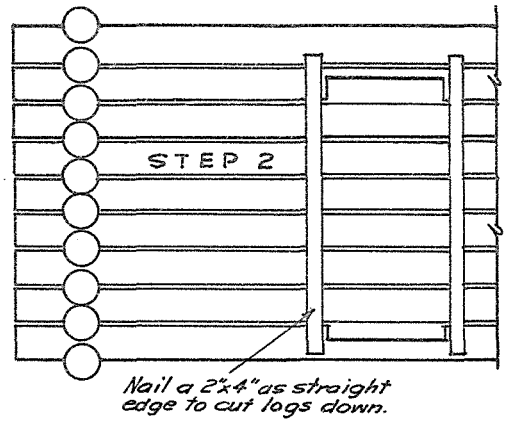
As soon as the first round of logs and the floor joists are laid, the location of each door and window opening should be spotted and marked permanently on the inside face of the logs. The door opening should be cut out and the notch chopped down to within an inch of the true line. The finishing should be left until the frame is set to preserve the surface of the wood. The height of the opening above the floor line should be determined and marked on the bottom log for reference so that the necessary cuts can be made in the top log over the opening before it is put in place. When the log that carried the window sill is reached, the cuts for the window must be made the same as for the doors.

The logs should not be cut out of the space between the bottom and top of the opening until the log work of the building has been completed and the roof put on. It is very desirable that the building be allowed to settle and dry out for several weeks before this is done, even if the logs are well seasoned. This is not always possible because of the necessity of getting the job done promptly. When the last log over the opening is reached, it should be notched before it is put in place. The next log below it should be sawed half way through to serve as a guide for the saw in cutting out all of the logs in the opening. When the logs are to be cut out of the opening, a 2 x 4 should be nailed along the side to serve as a straight-edge in making the saw cut. It will also hold the logs until the false jamb can be placed in the opening.

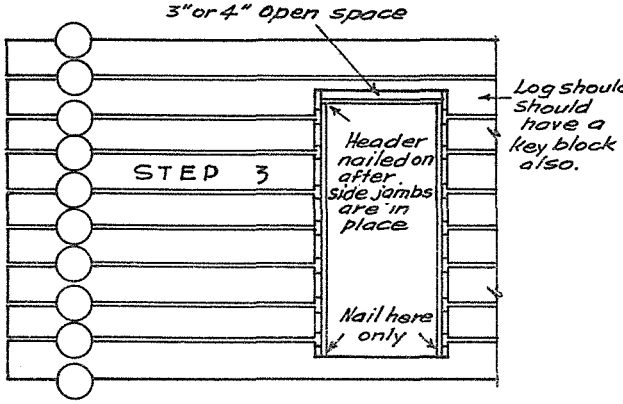
Where an excellent job is desired, a false jamb may be prepared and set in place as shown on Pages 194 to 196. It is essential that sufficient space be left above the jamb to allow for the logs to settle. If the logs are well-seasoned, and the building has been allowed to settle, it may be satisfactory to nail the false jamb to the ends of the logs. This is especially true on smaller buildings where the appearance is not so essential.

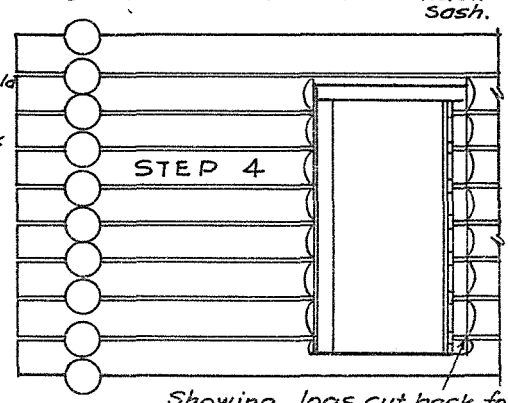
The width of the jambs will vary with the size of the logs in the building. For logs which average 12", the jambs should be of 10" material, and for logs 10" or under, 8" material should be used. It will be necessary that the logs on each side of the opening be cut down flush with the opening jambs so that the casing will fit properly and set flush with the jambs.





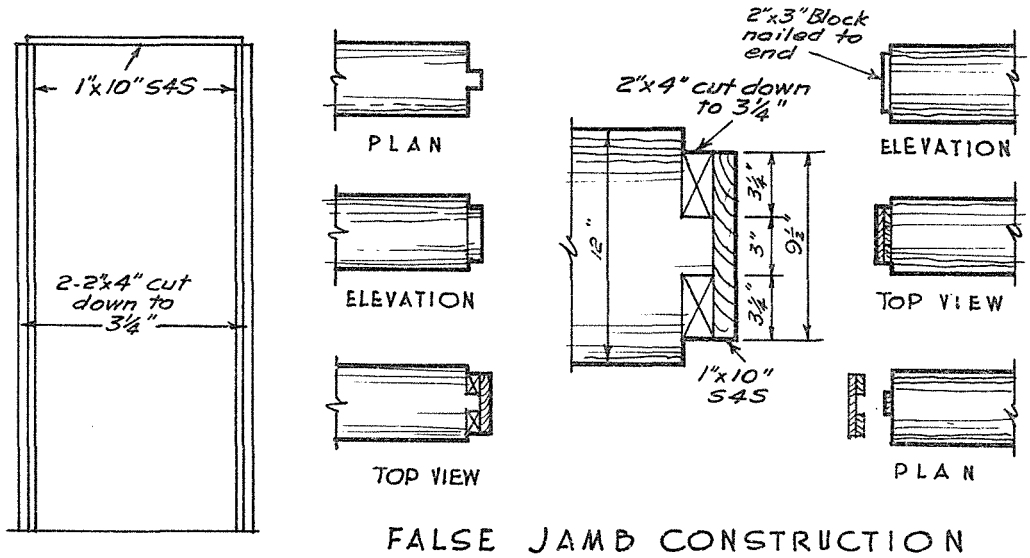
NOTE: Openings will usually be from 6½" to 7" wider than door or window sash.


3" or 4" open space
Log should Should have a key block also.
STEP 3
Header nailed on after side jambs are in place
Nail here only



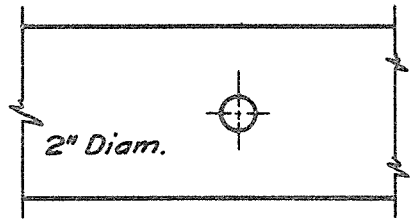
False jamb in place, nailed to bottom log only. Nail header after side jambs are in place. Logs are free to settle, yet the false jamb to which finish frame is attached is held securely in place. Nail casings to false jambs, and not the logs.

FRAMING OPENINGS

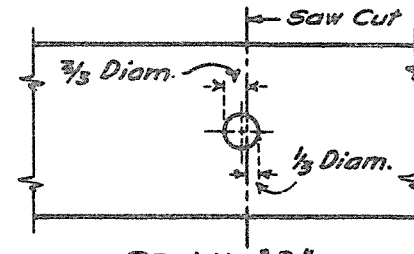


FALSE JAMB CONSTRUCTION

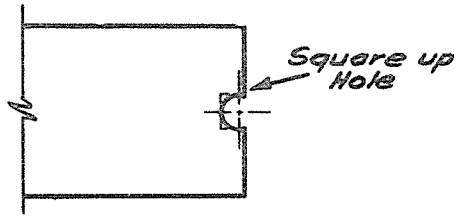
FRAMING DOOR OPENING



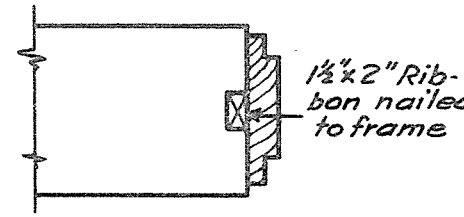
DETAIL "A"



DETAIL "B"

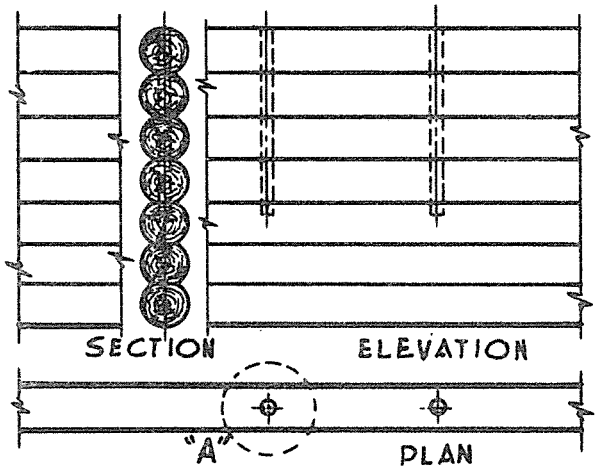


DETAIL "C"



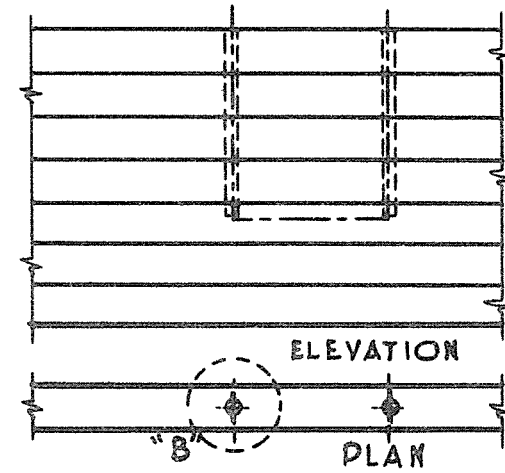
DETAIL "D"

Drill 2" Hole - Depth of Jamb



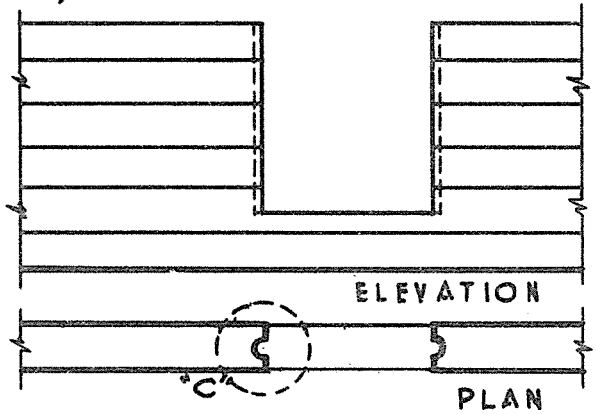
STEP 1

Saw cut line thru Hole



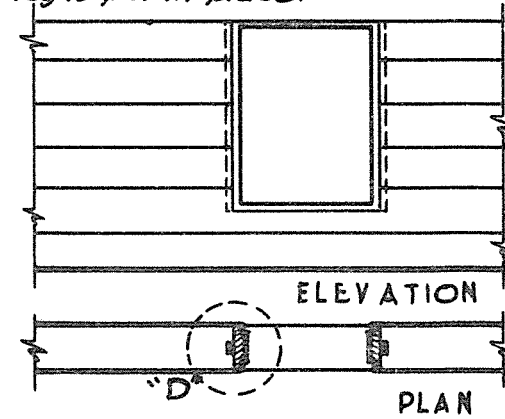
STEP 2

Hole to be bored as each log is put in place.



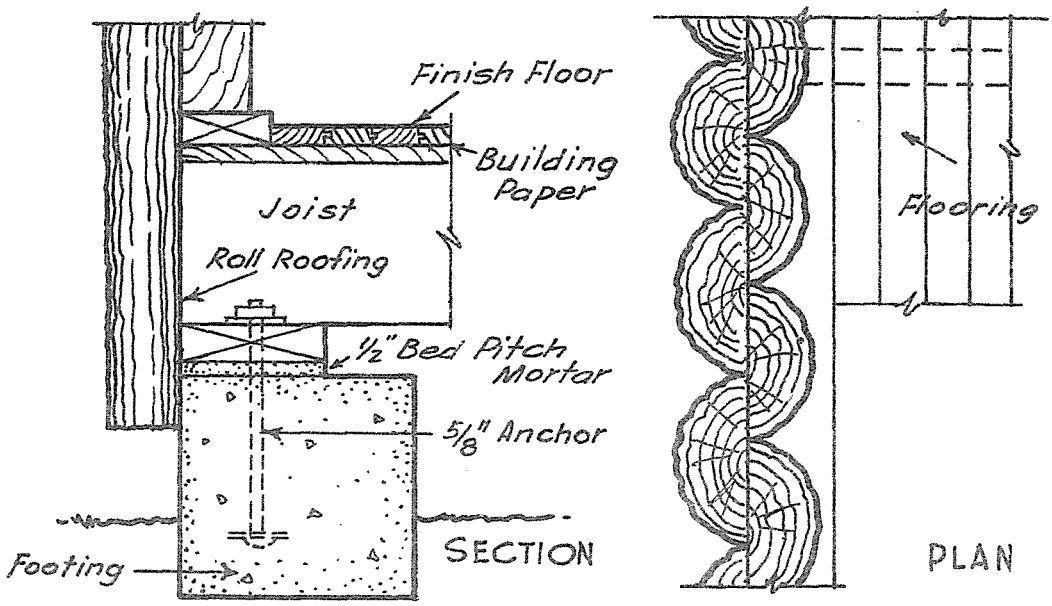
STEP 3

Frame to be inserted before top log is put in place.



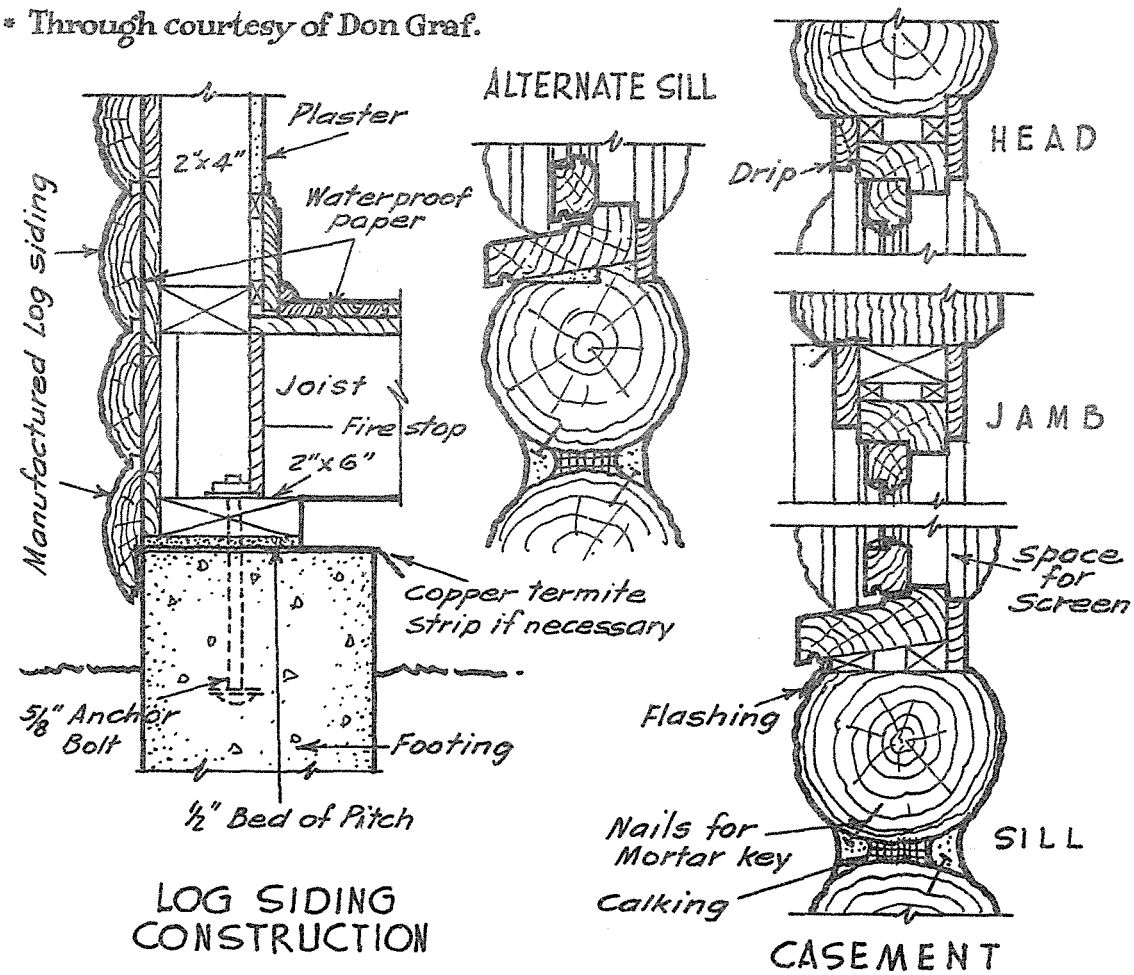
STEP 4

FRAMING WINDOW OPENINGS



POLE CONSTRUCTION

* Through courtesy of Don Graf.



LOG CONSTRUCTION

129. Roof Logs

Roofs on log buildings may be framed in several different ways, depending upon the kind of material available and the appearance desired. With a shingle roof, the rafters, whether of sawed material or round poles, will be framed in the same way as the roof of a frame building. The only difference is that the top log on the wall must either be framed or notched out to make a seat for the rafters. All roof framing must be securely nailed. Both methods are shown on Pages 198 and 199. The gable ends may be run up with logs, which is most desirable for appearance, or they may be framed similarly to the gables in a frame structure.

With a shake roof where the shingle type of laying is not used, rafters are not necessary, but roof logs running parallel to the side walls may be placed at intervals for the shakes to rest upon. Shakes 30" in length are necessary with roof logs spaced at 24" intervals. The gable logs are run up at the same time as the roof logs, and the two are framed together. Building roof trusses or ties should be used above the square of wall where they are required for safe construction.

Some skill with an axe is required to face or hew round timbers to have one or two sides with flat surfaces for framing. There are a number of mechanical iads which should be used by anyone engaged in doing any form of log construction work.

A carpenter's spirit level, a steel square and a chalk line and chalk are necessary for laying off the lines to be followed in hewing a timber. The log to be framed should be laid on the skids or horses and dogged in place. The desired dimensions should be marked on each end of the log with the aid of the level and the square. The level will insure that lines on each end are parallel to each other. The chalk line is used to snap lines which connect similar points on each end of the log. The axe is then used to cut out between the marked lines.

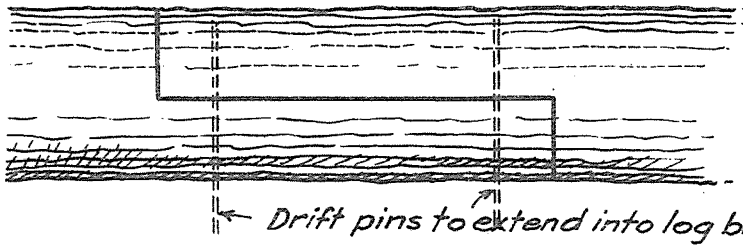
A mitre box to guide the saw can be used to good advantage for squaring the ends of timbers and for cutting pole rafters. A steel tape or a board pattern cut to the desired length should be used for measuring lengths. See page 200.

130. Second Floor Joists

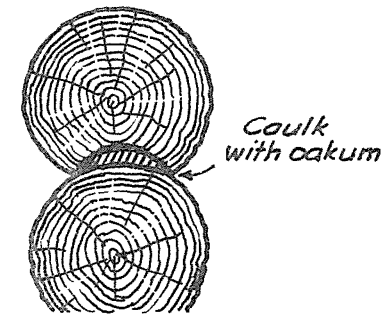
For a 1½-story or 2-story building it is necessary to put in floor joists at the proper height. This is done by notching into the wall log about half way so that the ends of the joists will set into the side wall.

131. Finishing Log Walls

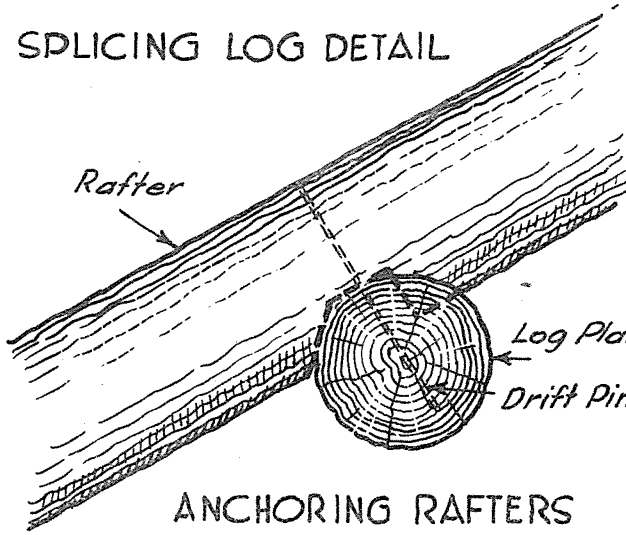
If the logs in buildings are scribed or carefully fitted together, it will seldom be necessary to put in chinking. Whenever chinking appears to be necessary, it is good practice to use small poles which run the full length of the wall. This makes a much



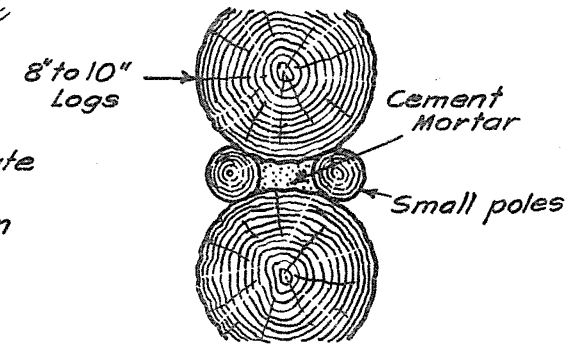
SPLICING LOG DETAIL

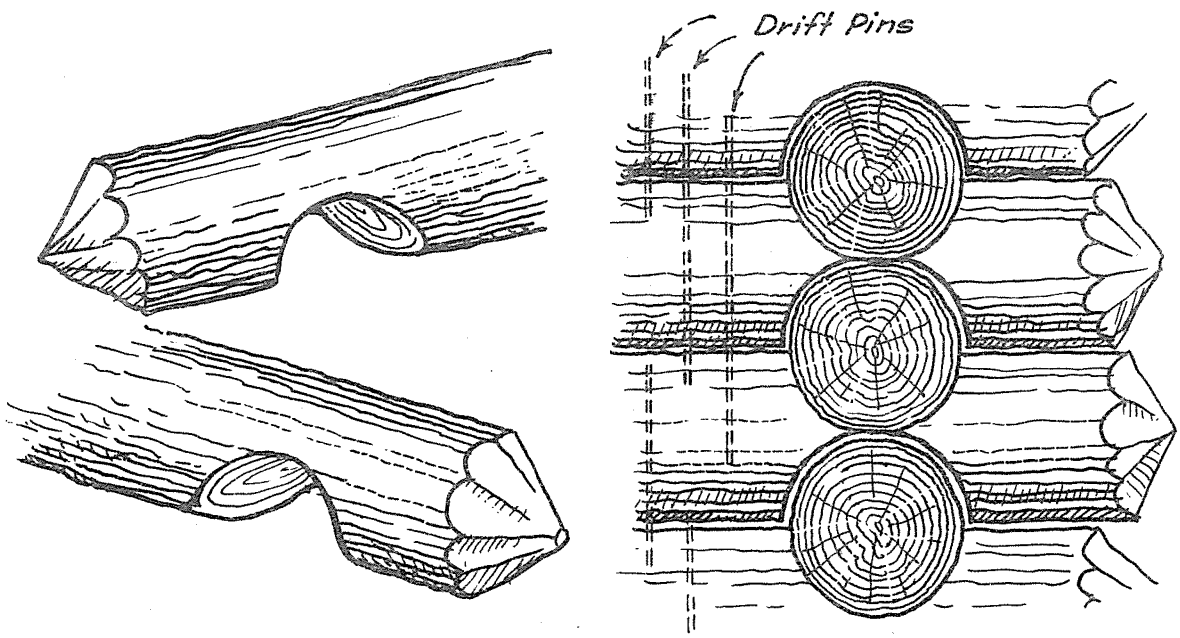


JOINT WEATHERPROOFING METHODS



ANCHORING RAFTERS

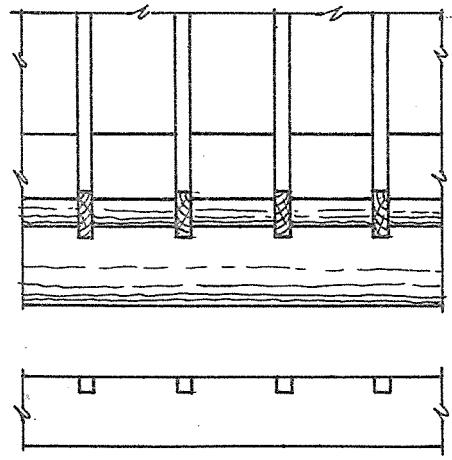




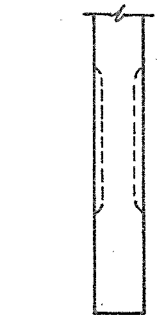
COPING OR CUTTING DETAILS

General Note: Drift pins should penetrate thru two and into the third log, spaced at corners and openings and approximately 6ft. on centers along walls. Holes for drift pins should be drilled 1/16" to 1/8" smaller than diameter of pin.

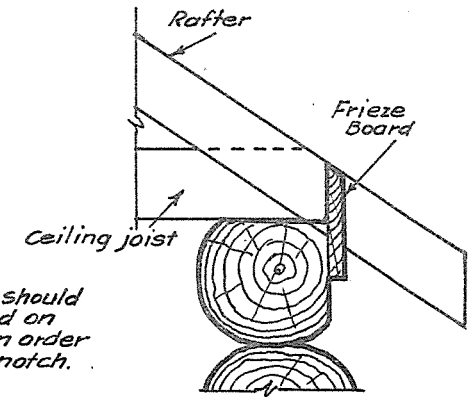
LOG CONSTRUCTION



The top log is flattened on top and roof seats are notched down.

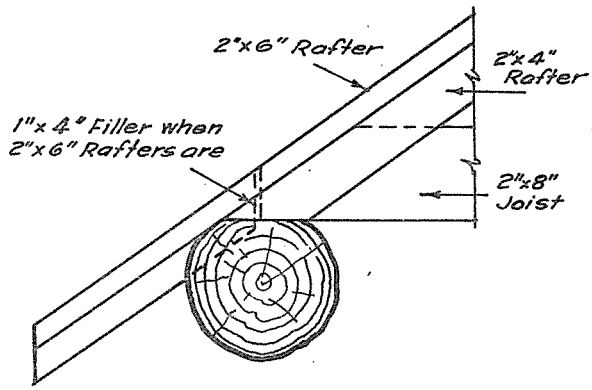


Pole Rafter should be flattened on two sides in order to fit into notch.

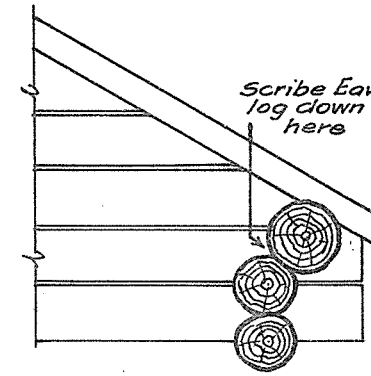


Top log is squared on two sides to make regular plate for roof rafter and ceiling joist.

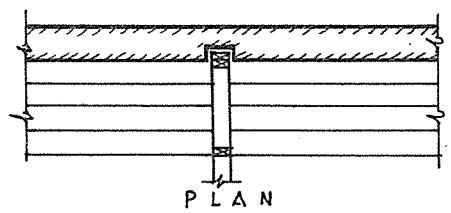
ROOF FRAMING



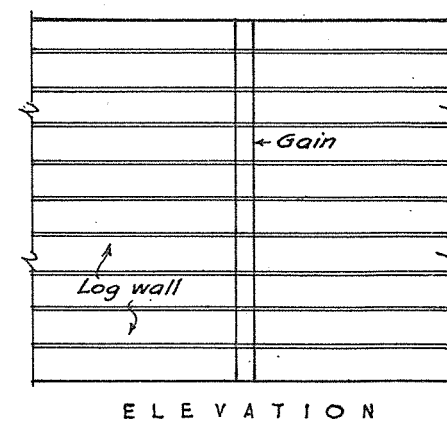
Hew top of log down to average width of 6", then notch down for each rafter. Be sure rafter cut makes a snug fit.



Method of construction of eave log in heavy snow country.

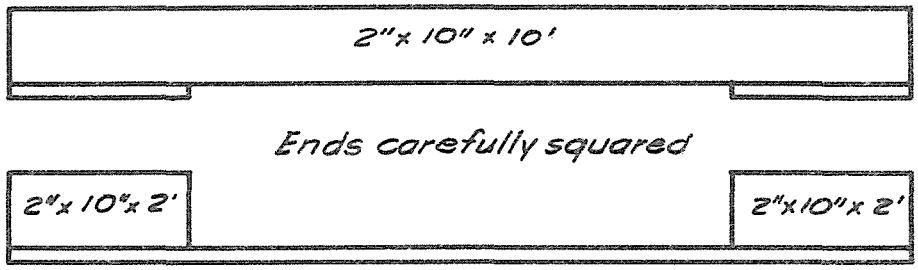


Cut a gain 2" in depth and the width of a 2"x4" (3⅝") into the face of each log before it is finally placed. Then set stud of partition in the notch, but do not nail.

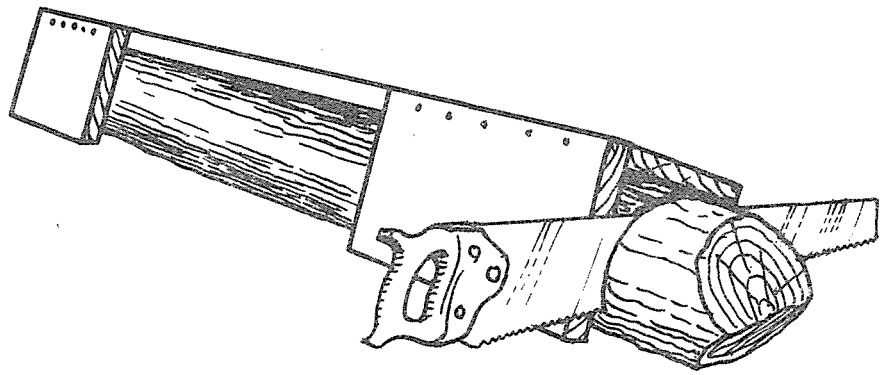


FRAMING PARTITIONS

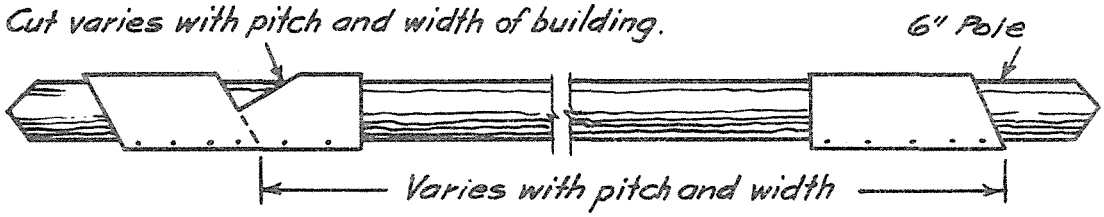
ROOF AND PARTITION FRAMING

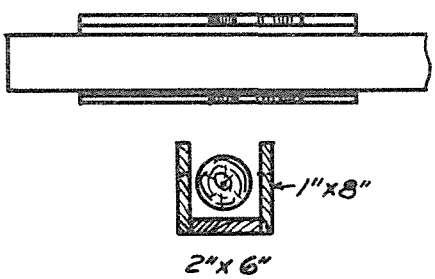


With this mitre box, logs may be cut exactly square at either end.



SAWING LOG END SQUARE



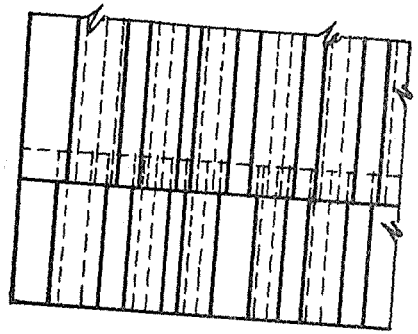


Make each box separate and then fasten to the top of a log or on the floor, the correct distance apart. Lay the pole in the box, dog it fast and then saw to the pattern. This is much faster than marking each pole separately and every rafter will be the same.

For Pole Rafters, line and hew upper surface to get a face and a good even bearing for boards.

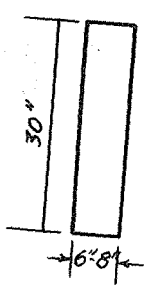
FRAMING POLE RAFTERS

LOG CONSTRUCTION

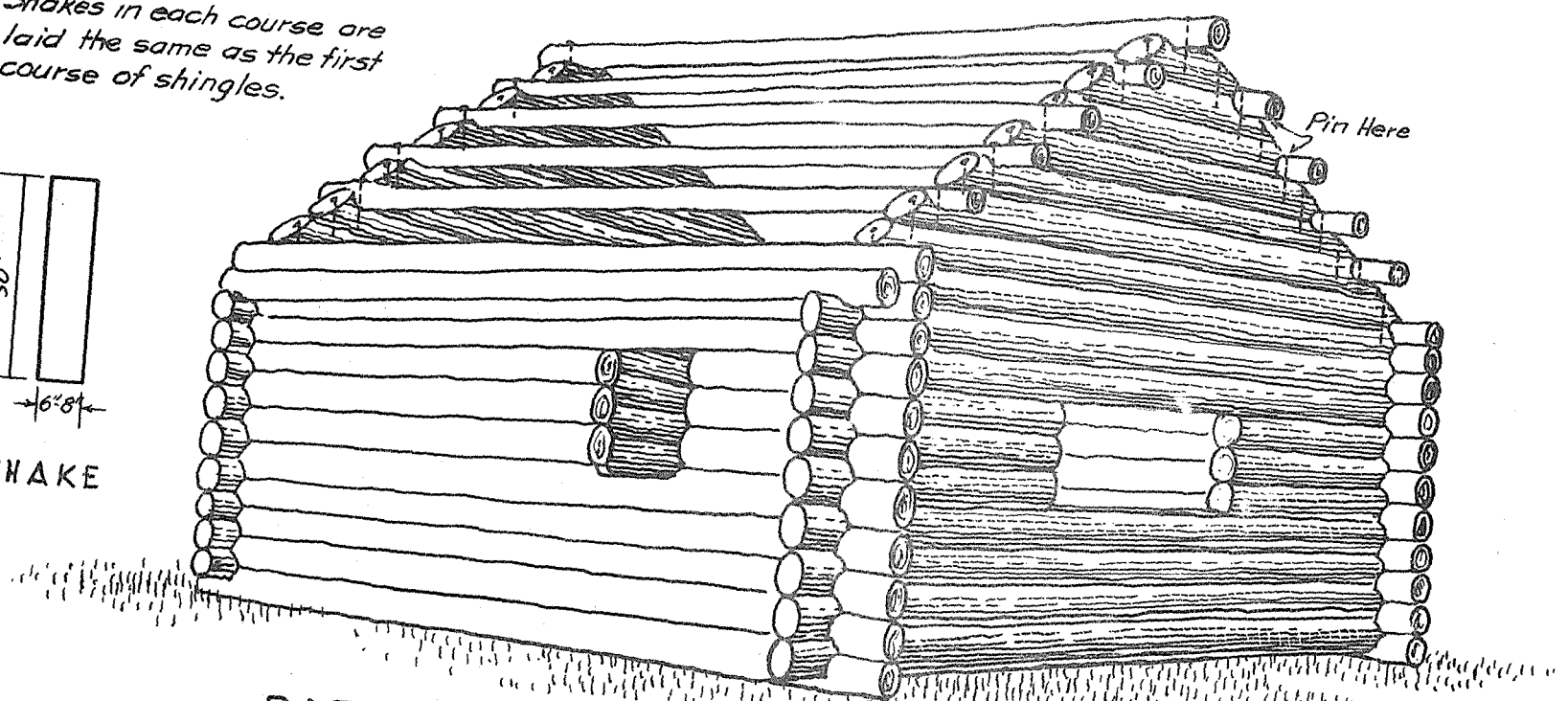


Shakes in each course are laid the same as the first course of shingles.

FRAMING POLE RAFTER ROOF FOR SHAKE ROOF



SHAKE



RAFTER FRAMING FOR SHAKE ROOF

better looking job and is easier to put in than the split chinking. It has always been a considerable problem with log structures to devise some method by which the plaster daubing in the wall can be held in place. One method calls for driving shingle nails into the log two or three inches apart, from one end of the crack to the other. A second method mixes hair with the plaster on the assumption that the hair would help the plaster to hang together. A third method tried to hold the plaster by nailing strips, like pieces of window stop, on the lower log. This appeared unsightly and detracted from the general appearance of the building to which it had been applied. A fourth method tacked narrow strips of 1/2" mesh wire screen, or window guard, into the crack. This has been about as successful as any method tried. A fifth method laid a layer of moss or a strip of balsam wool on each log before the next log was placed. The moss which projected beyond the crack presented a surface which tended to hold the plaster in place.

The most satisfactory material of all those experimented with is a tar and oil product which is applied to the cracks between the logs and elsewhere, with a pressure grease gun having a half inch nozzle and a trigger release. The logs should be laid tightly together and must be dry when the seal is applied. The seal material should be heated to a temperature of about 65° F. It is important to apply the proper quantity of the material. A thickness of about 1/4" gives good results, and allows the material to "give" as the logs contract and expand, insuring a permanent joint. If the material is applied in any less amount, it does not have body enough to stick together. It has a greater power to stick to the log than to itself.

132. Pole and Log Siding Walls

Manufactured shiplapped log siding may be used horizontally over sheathing in the same manner as any other siding. This material may also be used to simulate pole construction, if a proper waterproof building paper or roll roofing is placed between the logs and sheathing. See Page 196.

Pole houses are buildings with walls made by placing the logs on end. Such structures are easier to build than those in which the logs are horizontal because one man can handle the logs, which are usually short length and small diameter. The labor of notching at the corners is not required as with horizontal log construction using large logs. The poles should be not less than 4" in diameter. If full round logs are to be used, they should be hewn on the sizes and matched to fit closely to insure a weather-tight wall. The cracks are chinked in the same manner as in horizontal log construction.

A good foundation should be provided, and square sill logs should be bolted to it. The sill logs should equal in diameter, or hewn dimension, that of the wall poles. The top surface of the sill must be level to provide a proper bearing for the sawed ends of the poles. Similar logs must be used for plates over the tops of the verticals. The sills and plates should be halved and lapped at the corners. The corner uprights should be set first, and the plates

placed on top of them. The wall uprights are then matched and fitted between the sills and plates and spiked in place.

Split logs and slabs are sometimes used as illustrated on Page 196. Two layers of logs or slabs are used, with staggered joints and roll roofing or heavy building paper between them. Edges of slabs should be cut to make close joints.

133. Shake Roofs

The use of split shakes for roof coverings adds to the appearance of log buildings. They are usually more economical than sawed shingles because of the expense of hauling. Shakes are usually 30" long and are laid in double courses with a lap of 6" between courses. They should overlap at least 1-1/2". A more detailed description of shake shingles is given in Chapter XIX.

References:

R-1 Handbook - Construction and Maintenance of Improvements
Pencil Points Data Sheets, by Don Graf
Standard Details - R-5 and R-8

CHAPTER XIV - CONCRETE CONSTRUCTION

134. General.

The two principal requirements of hardened concrete are strength and durability - strength to perform the functions of the structure, and durability to resist the exposure of the elements. These two considerations should govern the design of the mixtures. To them should be added two other considerations which are very important - economy and workability. The mixture should be designed to give the maximum amount of strength with the use of a minimum amount of cement. The mixture must also be workable while being placed.

A successful design will achieve a proper balance of these four essentials; the mixture will be placeable in the proper degree; it will represent an economical use of the available materials, and when hardened, will provide the necessary strength and resistance to the weathering agencies.

135. Materials Used in Making Concrete.

The three principal components of good concrete are cement, aggregate and water. Under certain conditions it may be necessary to hasten the setting of concrete and for this purpose an addition of a chemical admixture may be necessary. Some construction calls for reinforced concrete. When this is necessary the reinforcement must meet certain special requirements. The various material requirements are described in this article.

A. Cement.

All cement used in Forest Service construction work must be an approved standard brand of Portland Cement, complying with Federal Specifications SS-C-191a and the rules of the Portland Cement Association. If high early strength Portland Cement is used it must comply with Specification C-74-30-T of the American Society for Testing Materials. Cement must be protected from moisture and under no conditions should lumpy cement be used.

B. Aggregates.

Aggregates should be tough, hard, and free from dirt, loam, clay or vegetable matter. They must not contain strong alkali or organic material which gives a color darker than the standard color when tested for organic impurities. Aggregates are of two classes, fine and coarse.

(a) Fine Aggregate.

Fine aggregate may consist of natural sand, prepared stone sand, prepared blast furnace slag sand, or, subject to approval, other inert materials having similar characteristics. It should be well

graded and should contain no particles larger than the size which will just pass through a No. 4 sieve. Well-graded sand aids in filling the voids between the coarser particles and results in a dense concrete. Fine aggregate must comply with all requirements of Federal Specifications SS-A-281 for Class 1, Grade A aggregate.

(b) Coarse Aggregate.

Coarse aggregate may consist of crushed stone, gravel, blast furnace slag, or, subject to approval, other inert materials having similar characteristics. It should be tough, hard, and free from impurities. It should be well-graded with sizes ranging upward from a No. 4 sieve to the maximum size required for the work to be done. The maximum size is usually not more than 2 inches, but it should never exceed 1/3 of the thickest section of concrete in which it is to be used. Coarse aggregate must comply with Federal Specifications SS-A-281 for Class 2, Grade A aggregate.

(c) Bank Run Material.

Bank run material is a natural mixture of sand and gravel as it is taken from the pit or from a stream bed. It is seldom suitable for concrete until it has been screened and recombined in the correct proportions. Care should be exercised in the use of bank run material, because of the possibility that it may contain a large amount of organic material. This is especially possible when the aggregate is obtained from a stream which receives the waste products of manufacturing plants.

C. Water.

Water used for mixing concrete must be clean and free from strong acids, alkalis, oil and organic materials. As a general rule, water that is suitable for drinking purposes, will be suitable for concrete.

D. Reinforcement.

Reinforcement for concrete may consist of steel bars or steel wire fabric. The bars should be Type B, deformed, grade 2 intermediate billet steel, conforming to Federal Specification QQ-B-71. Steel wire fabric must be woven or electrically welded and should conform to Specification A-82-34 of the American Society for Testing Materials. The reinforcement should include all necessary metal bar supports, spacers, ties, etc. These should be of an approved design and should be strong enough to prevent displacement of the reinforcement while the concrete is being poured.

E. Admixtures.

Various substances are often added to concrete to speed up the setting, to improve its workability, to increase its waterproof qualities, to harden its surface or to lend to it other advantages. Patented admixtures whose composition is unknown should be avoided. Calcium chloride is often added to accelerate the setting of concrete.

Not more than 3% of calcium chloride to 97% of cement by weight should be used because of the possibility of reducing the strength of the resulting concrete. Hydrated lime and Kaolin are sometimes added to make the concrete more workable, but no more than 8% of either of these to 92% of cement by weight should be used. Many compounds for waterproofing concrete are now on the market. Most of them are very effective if used in connection with the finishing coat. Large masses of concrete can be waterproofed more effectively by careful attention to the proportioning and mixing of the materials and the placing of the concrete while the structure is being built.

136. Storage of Materials.

All materials used in the making of concrete should be carefully protected after delivery on the job. The cement must be protected from moisture. Aggregates may be stored outside but should be kept free from foreign matter. Reinforcing material should be stored in a dry place to prevent oxidation.

137. Testing Aggregates.

Before concrete work is started and during the entire progress of the work certain tests should be made to determine the suitability of the aggregates. It may be advisable to make these tests several times a day during the early part of the work, but if the results are fairly uniform, tests may be made at longer intervals.

A. Test for Organic Impurities.

The suitability of fine aggregate from the standpoint of organic matter, may be determined by the "colorometric test for sands." This test was developed by the Lewis Institute and is available in printed pamphlet form through the Portland Cement Association. The apparatus used for making the test is very simple and may be purchased at most drug stores at a slight cost.

B. Sedimentation Test.

The following test is often used in the field to show the approximate quantity of clay and silt in sand. This is not an A.S.T.M. standard, and should not be confused with the "Decantation Test." A 32-oz. graduated prescription bottle is filled to the 14-oz. mark with sand. Clear water is added to bring the mixture up to the 28-oz. mark. The mixture is shaken vigorously, and the contents are allowed to settle for one hour. If more than 1-oz. of sediment appears above the aggregate, the sand should be rejected. The sand may be subjected to washing and samples again tested, and the sand approved for use if the test requirements are fulfilled.

C. Grading Test.

The grading of aggregates may be checked for uniformity by making sieve analysis tests. In these tests the particles are divided into the various sizes by standard sieves.

D. Moisture Test.

Aggregates should be tested frequently to determine the amount of moisture they contain. This test is of great importance if the concrete mixture was designed according to the water-cement ratio, as described in Article 140-A. The amount of moisture held by the aggregate will vary from time to time with changing weather conditions. Changes in moisture content of coarse aggregate are infrequent, but the moisture in sand may vary sufficiently to effect the mix. A simple method of determining the percentage of moisture in sand is to weigh a sample of the damp sand and then dry it in an oven or over an open fire until all the moisture has been driven off. After this has been done the sample is again weighed and the percentage of moisture is found to be:

$$100 \times \frac{\text{Wet weight - dry weight}}{\text{dry weight}}$$

138. Concrete forms.

It is essential that forms for concrete construction be built true to line and grade, and that they be sufficiently strong to support the weight of the plastic concrete and the additional loads which may be put upon them during construction. Forms should be built tight enough to prevent any appreciable leakage of mortar. They are usually built of lumber, but certain types of construction require metal forms. The use of metal will not be considered in this article.

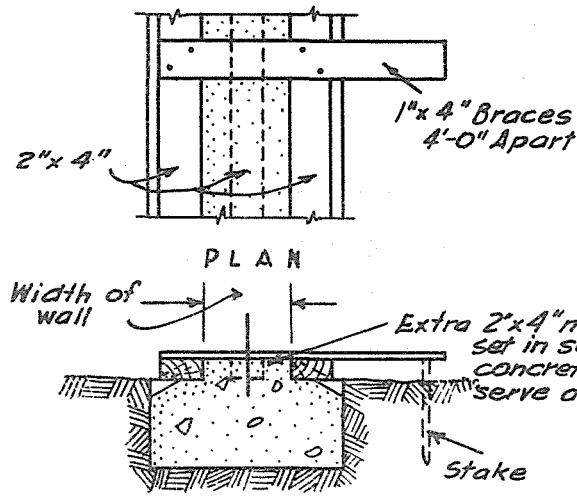
Any good sound lumber which is generally free from knots, shakes or decay may be used for forms. No. 1 common is usually used, but No. 2 common may be used if long pieces are not required. Lumber which is to be used for sheathing or sub-flooring may be used as form material. Plywood is used to advantage in some types of construction. All form lumber should be surfaced, and for careful work, air-dried or kiln-dried material is preferable.

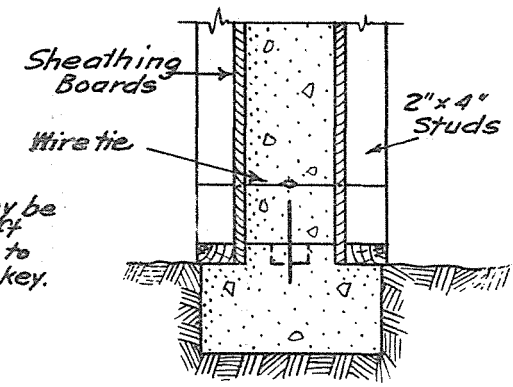
Forms should be designed to withstand the weight of the plastic concrete, which is estimated to be 150 lbs. per cu. ft., plus the construction load, which is usually assumed to be 75 lbs. per sq. ft. of floor area. The supporting members should carry such weights with a minimum deflection of not more than 1/360 of the length of the span. The strength of forms for columns and walls should be sufficient to resist the hydrostatic pressure of the plastic concrete, which is assumed to be 150 lbs. per sq. ft. for each foot of height.

Forms should be constructed so that they may be removed without damage to the concrete or to the form lumber. The inside of the forms should be carefully cleaned and should be dampened immediately before pouring concrete. The construction of some types of forms is shown on pages 209, 210 and 211 .

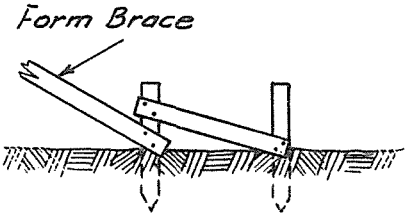
139. Placing Reinforcing Material.

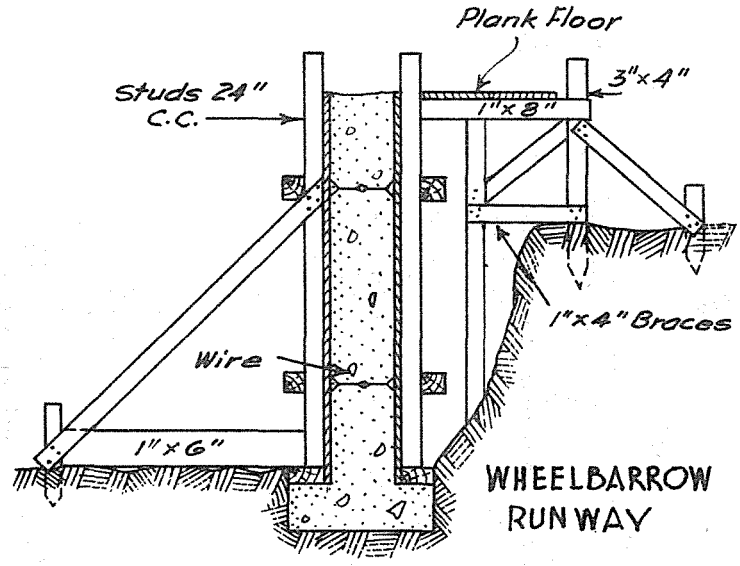
Reinforcing rods and fabric, anchors and dowels, must be placed in position according to the approved plans. Splices should be made only where shown. They should be well distributed and should not be

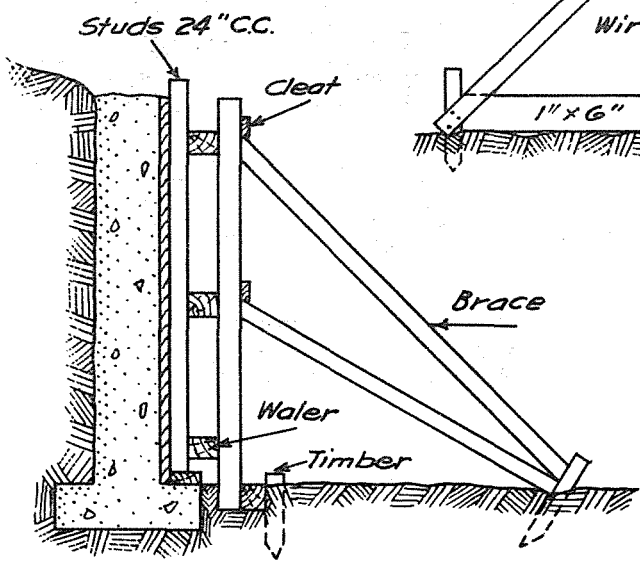




FOOTING FORMS

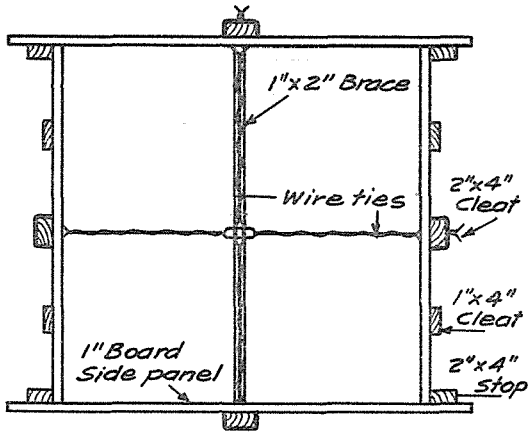




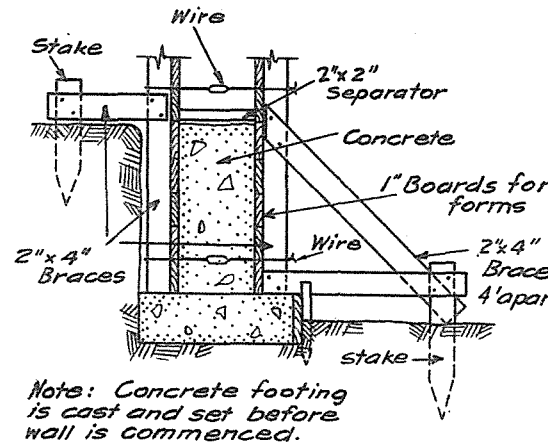


CONCRETE FORM BRACED WITHOUT WIRE TIES

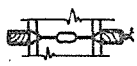
FORM CONSTRUCTION



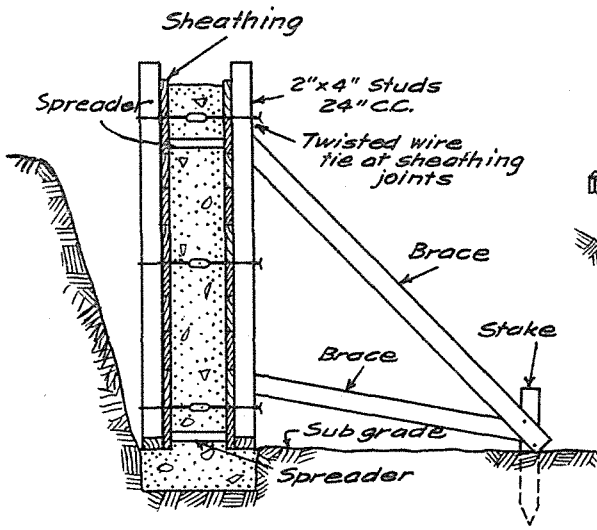
FORMS FOR BOX FOOTINGS



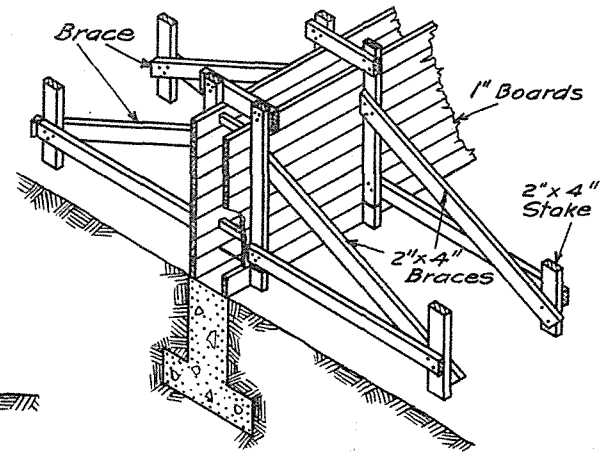
FORMS FOR CONCRETE WALLS ABOVE AND BELOW GRADE



Top view of wiring

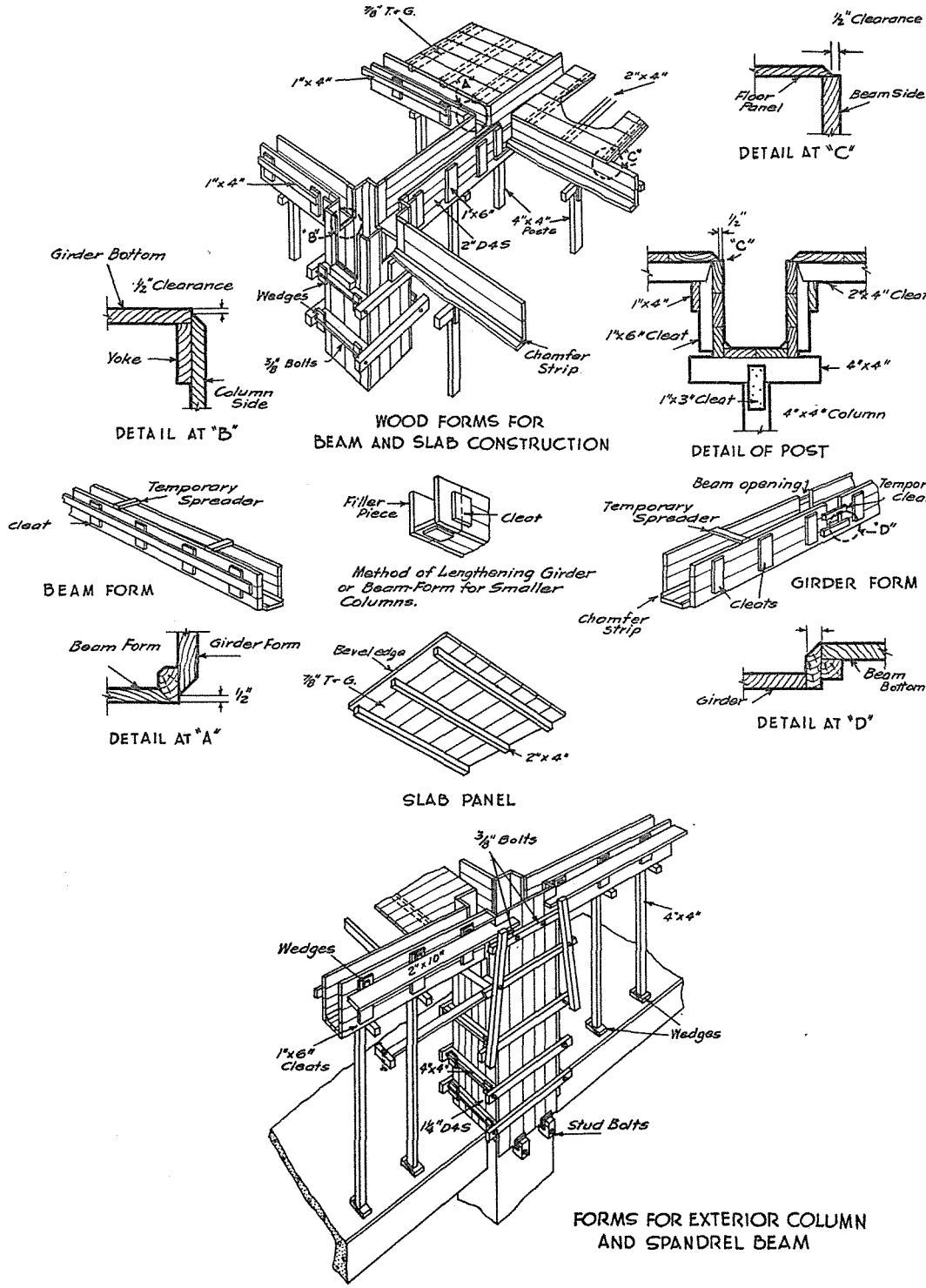


WALL FORM WITHOUT WALERS USING STUD TIES IN PAIRS

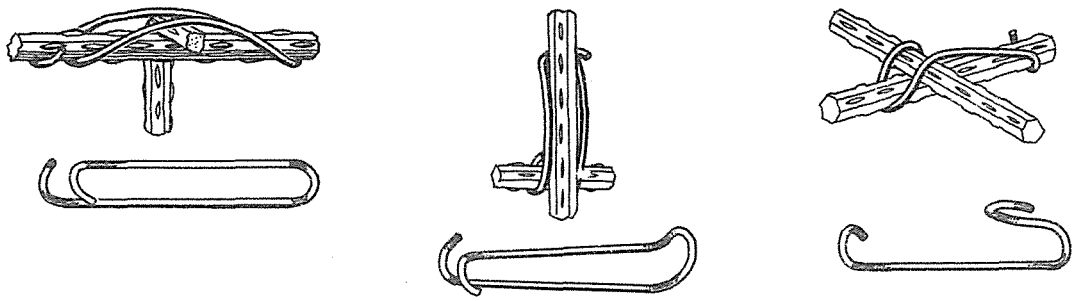


FORMS FOR MONOLITHIC WALLS ABOVE GRADE

FORM CONSTRUCTION

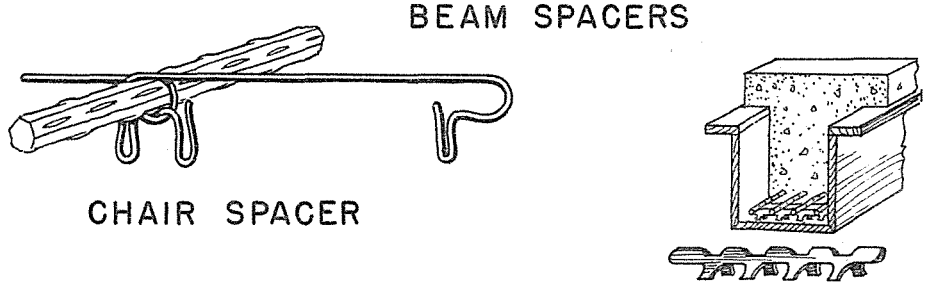


FORM CONSTRUCTION



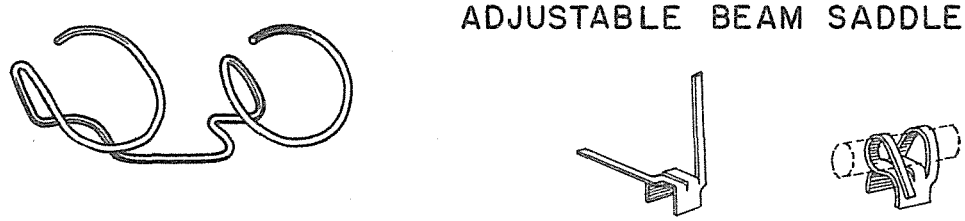
BAR TYPE

BEAM SPACERS

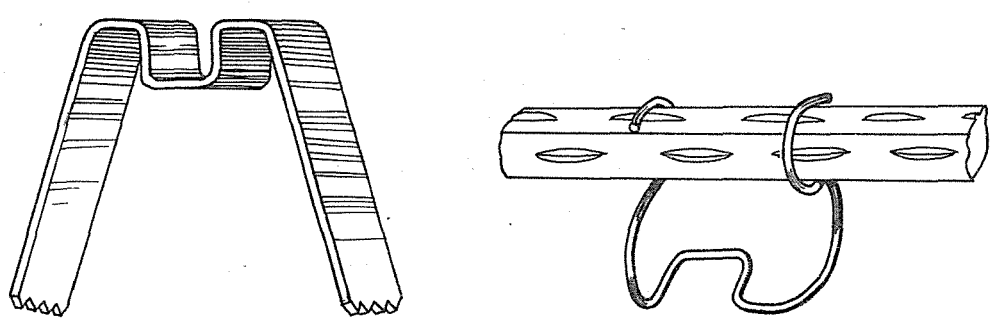


CHAIR SPACER

ADJUSTABLE BEAM SADDLE



CHAIRS



REINFORCEMENT FASTENERS

located at points of maximum stress. When bars are spliced they must be lapped for a length of not less than 40 times the diameter of the bars. They must be securely wired together at intervals along the entire length of the splice. Wire should be No. 14 gauge, black or galvanized iron. Information regarding various sizes of annealed iron wire is shown in the following table:

SIZE AND WEIGHT OF ANNEALED-IRON WIRE

A. S. & W. gage number	Diameter, inches	Feet to the pound	Area, square inches	Breaking strength, pounds	Safe load, pounds
4	0.225	7	0.040	2500	625
6	0.192	10	0.028	1800	450
8	0.162	14	0.020	1300	325
10	0.135	20	0.013	900	225
12	0.105	33	0.008	600	150
14	0.080	58	0.005	350	88
16	0.062	96	0.003	220	55
18	0.047	166	0.002	130	32

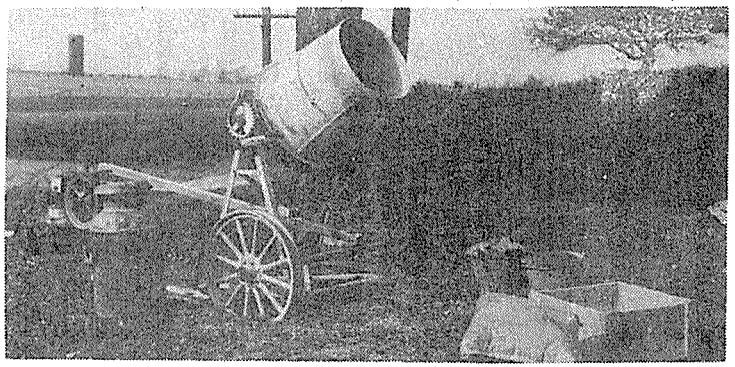
Standard construction practice requires that when concrete is deposited directly against the ground the reinforcement must be covered by at least 3 inches of concrete. When walls are exposed to weather, the minimum coverage of concrete should be not less than 2 inches. Fire resistant construction of buildings requires that at least 1 inch of concrete be placed over the reinforcement in slabs and walls and at least 1½ inches in beams, girders and columns.

140. Design of Concrete Mixtures.

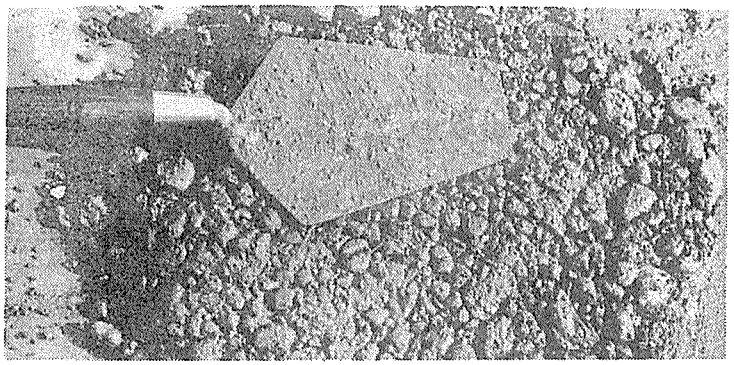
The design of concrete mixtures is based principally upon the relationship, established by extensive research, between the properties of the hardened concrete and the amount of mixing water used. By these extensive investigations in both laboratory and field, a fundamental law has been established which says: "For plastic mixtures using sound and clean aggregates, the strength and other desirable properties of concrete under given job conditions are governed by the net quantity of mixing water used per sack of cement." This law is known as the water-cement ratio law.

The combination of water and cement forms a paste which, upon hardening, binds the aggregate particles together. The strength of the paste is determined by the proportion of cement and water. Too much water dilutes the paste and reduces the strength. Too little water prevents the plastic mixture when combined with the aggregates and also reduces the strength. True plasticity means that the resulting concrete is neither too wet nor too dry.

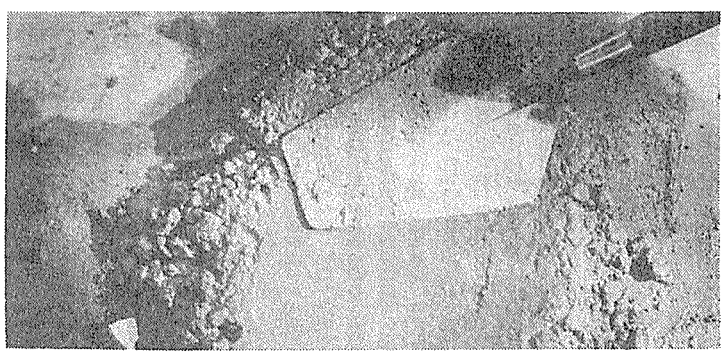
Designing a concrete mix, therefore, consists of selecting the water-cement ratio which will produce concrete of the desired resistance to exposure and the required strength, and finding the most suit-



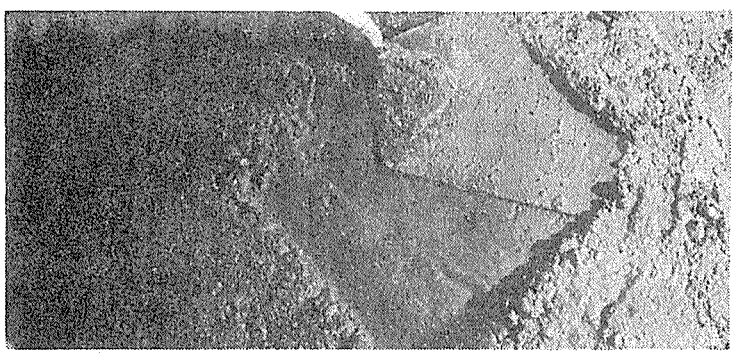
A mechanical mixer helps in securing a high quality concrete. Just as in hand mixing, correct proportions of cement aggregate, and especially water must be controlled. Materials should be mixed at least one and preferably two minutes to obtain good workability.



A concrete mixture in which there is insufficient cement-sand mortar to fill the spaces between pebbles. Such a mixture will be hard to work and will result in rough, honeycombed surface.



A concrete mixture which contains the correct amount of cement-sand mortar: with light trowelling all spaces between pebbles are filled with mortar. Note appearance on edge of pile. This is a good workable mixture and will give maximum yield of concrete with a given amount of cement.



A concrete mixture in which there is an excess of cement-sand mortar. While such a mixture is plastic and workable and will produce smooth surfaces, the yield of concrete will be low. Such concrete is also likely to be porous.

COURTESY OF PORTLAND CEMENT ASSOCIATION

CONCRETE MIXTURES

able combination of aggregates which will give the necessary workability when mixed with cement and water in this ratio.

A. Water-Cement Ratio.

The proper selection of the water-cement ratio, involves a consideration of both the degree of exposure to which the concrete will be subjected, and the strength requirements of the structure. Ample strength will usually be provided if consideration is given to the requirements of exposure.

The table on page 216 gives the recommended water-cement ratio on the basis of a definite minimum curing condition for concrete to meet different degrees of exposure in different classes of structures.

The types of structures given in the table are merely suggestive. The exact classification in individual cases will depend upon the conditions of exposure at the particular site. The classification is based on conditions prevailing in the greater part of the United States and assumes proper workability of the mixture through mixing, placing the concrete by puddling to fill the form completely and incorporate the reinforcement, and thorough protection from drying out or freezing during the early hardening period.

B. Consistency.

Consistency is a general term relating to the state of fluidity of the mix and embraces the entire range of fluidity from the driest to the wettest possible mixtures. The term plasticity describes a consistency of concrete which can be readily moulded, but which permits it to change form slowly if the form is removed. A plastic mass does not crumble, but flows sluggishly without segregation.

The term workability describes the ease or difficulty which may be encountered in placing concrete in a particular location. Workability is dependent upon conditions in which concrete is to be placed. The size and shape of the member being built and the spacing of the reinforcement may interfere with the ready filling of the forms. A plastic mixture containing a large size aggregate may be readily workable in a large open form, but may be difficult to handle in a thin wall containing a complicated system of reinforcement.

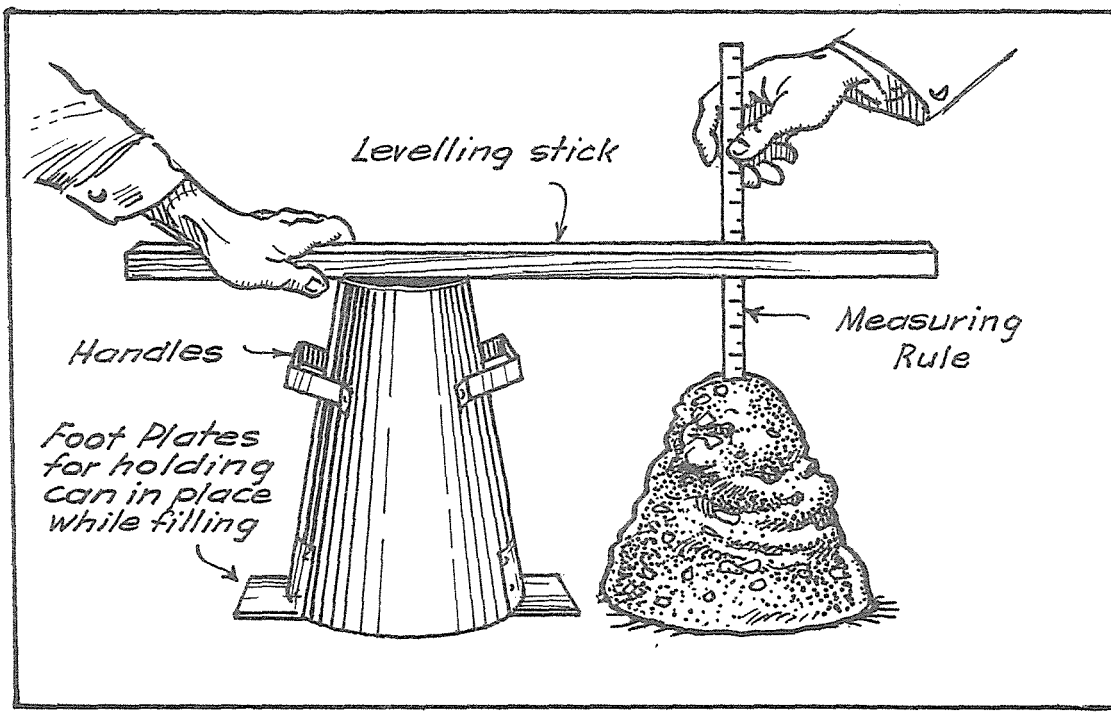
(a) Slump Test.

The slump test is a rough measure of the consistency of concrete. The concrete to be tested is placed in a mold formed in the shape of the frustrum of a cone. The bottom diameter of the mold should be 8 inches, the top diameter should be 4 inches, and the height should be 12 inches. The mold should be made of No. 16 gauge galvanized iron and should be provided with foot pieces to hold it steady while the concrete is being placed in it. It should also be provided with handles to facilitate lifting. The green concrete is poured in at the top and thoroughly tamped. The top surface is struck off smooth with a trowel, and the mold is immediately removed. The slump is then measured as shown in the illustration on page 217 .

WATER CEMENT RATIOS FOR DIFFERENT DEGREES OF EXPOSURE

These requirements are based on the use of concrete mixtures in which the cement meets the standard specifications of the A.S.T.M. and to which an early curing is given that will be equivalent to that obtained when protected from the loss of moisture for at least 7 days at a temperature of 70° F. For curing conditions less favorable than this, correspondingly lower water-cement ratios should be used.

Exposure \ Class of structure	Water-cement ratio, U. S. gal. per sack		
	Piles, thin walls: light members, columns & beams	Reservoirs, tanks, pressure pipes, sewers, canal linings, small dams	Heavy walls, piers, foundations heavy dams
Extreme:			
1. In severe climates like in Northern U. S., exposure to alternate wetting and drying, freezing and thawing, as at the water line in hydraulic structures.	5	5	6
2. Exposure to sea and strong sulphate waters in both severe and moderate climates.			
Severe:			
3. In severe climates like in northern U. S., exposure to rain and snow, and freezing and thawing, but not continuously in contact with water.	6	6	6
4. In moderate climates like southern U. S., exposure to alternate wetting and drying, as at water line in hydraulic structures.			
Moderate:			
5. In climates like southern U. S., exposure to ordinary weather, but not continuously in contact with water.	6	6	7½
6. Concrete completely submerged, but protected from freezing.			
Protected:			
7. Ordinary inclosed structural members; concrete below the ground and not subject to action of corrosive groundwaters or freezing and thawing.	7½	6	7½



MEASURING THE SLUMP

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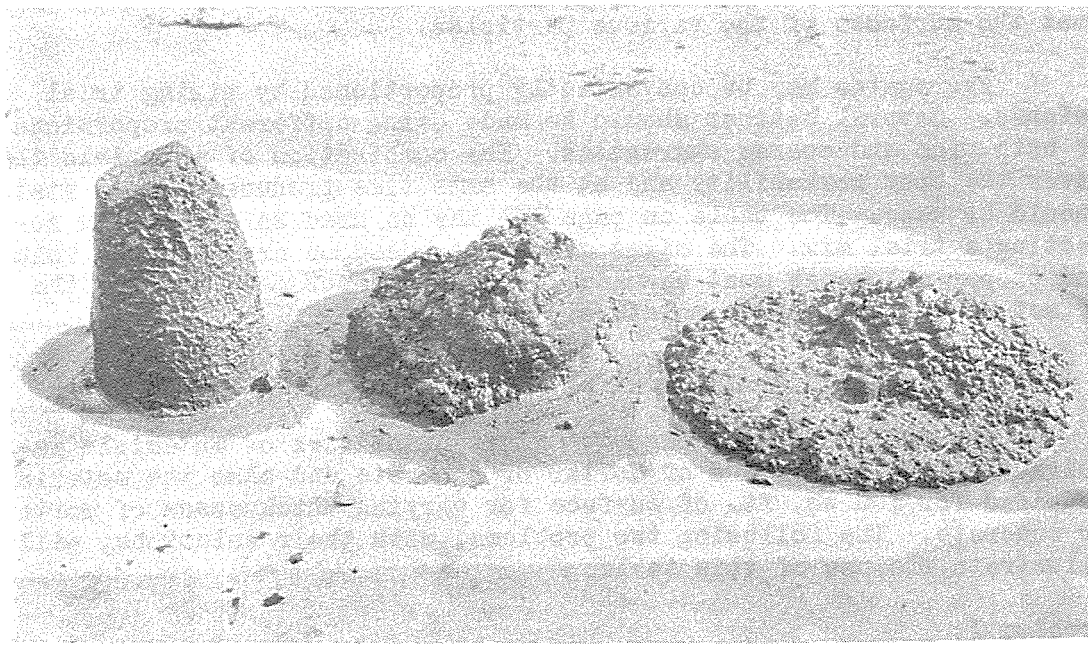


Stiff, medium and wet mixes of concrete. The stiff mix is suitable for foundations, floors and work of that character. The medium mix is suitable for tank walls, fence posts and similar work. The wet mix is used only for very thin sections like vases and garden furniture.

SLUMP FOR CONCRETE

Recommended slumps for different types of structures are given in the following table:

RECOMMENDED SLUMPS FOR CONCRETE

Type of Structure	Slump in Inches	
	Minimum	Maximum
Massive sections, pavements and floors laid on ground	1	4
Heavy slabs, beams or walls	3	6
Thin walls and columns, ordinary slabs or beams	4	8

C. Proportioning Aggregates.

The desirable proportion of aggregates to be combined with water and cement is that which will give the most economical results consistent with proper placing. The relative proportions depend, not only on the consistency of concrete required, but on the grading of the aggregates. A properly proportioned combination of fine and coarse aggregates contains all sizes between the smallest and the largest, without an excessive amount of any one size. In this combination a larger amount of voids are filled and less cement will be necessary to coat the surfaces of the various particles.

Aggregates may be conveniently proportioned by mixing trial batches. Several batches should be made using different proportions of both fine and coarse aggregates. The combination of materials that gives the best workability and at the same time produces a good yield, should be used. The table on page 219 may be used as a guide in selecting a trial mix. The mixes given are based on dry, compact volume, and proper allowance must be made for loose measurement and for the effect of bulking due to moisture.

141. Calculation of Quantities.

The table shown on page 220 gives quantities of materials required for one cubic yard of mortar or concrete and also the materials required for 100 sq. ft. of surface for varying thicknesses of mortar or concrete. The following two problems, with their solutions, will illustrate the use of this table:

Problem I:

What quantities of materials are required for a monolithic concrete foundation wall 34 feet square, outside measurements, 12 inches thick, 7 feet high, with a footing 12 inches thick and 18 inches wide, using a 1-2½-3½ mixture in both the wall and footing?

Solution:

The wall, exclusive of footing, contains 924 square feet of surface, 12 inches thick, deducting the duplication at corners.

TRIAL MIXTURES FOR VARIOUS WATER-CEMENT RATIOS

Water-cement ratios indicated include moisture contained in the aggregates.

Proportions are given by volume, aggregate dry and compact. Thus 1-2-3½ indicates 1 volume of cement, 2 volumes of sand and 3½ volumes of coarse aggregate.

If the aggregates are to be measured in the damp and loose condition they will occupy greater volume than when dry and compact. Amount should be determined by test. Approximate average value for sand 20 percent, for coarse aggregate, 6 percent.

For approximate proportions by weight add 15 percent to proportions of aggregate shown in the table.

The mixes are given as a guide only. The first batch should be made with measured water content and the proportions thereafter adjusted to give the desired workability, maintaining the specified water-cement ratio.

Slump Inches	Trial Mix, Dry Compact Volumes for Maximum Size of Aggregate Indicated	
	1 inch	2 inches
Water-Cement Ratio, 5½ Gallons per Sack		
½-1	1-2-3	1-2-3½
3-4	1-1 3/4-2½	1-1 3/4-3
5-7	1-1½-2	1-1½-2½
Water-Cement Ratio, 6 Gallons per Sack		
½-1	1-2 1/4-3 1/4	1-2 1/4-4
3-4	1-2-3	1-2-3½
5-7	1-1 3/4-2½	1-1 3/4-3
Water-Cement Ratio, 6 3/4 Gallons per Sack		
½-1	1-2½-3½	1-2½-4
3-4	1-2 1/4-3 1/4	1-2 1/4-3 3/4
5-7	1-2-3	1-2-3½
Water-Cement Ratio, 7½ Gallons per Sack		
½-1	1-3-4	1-3-4 3/4
3-4	1-2½-3 3/4	1-2½-4 1/4
5-7	1-2 1/4-3½	1-2 1/4-3 3/4

QUANTITIES OF MATERIALS FOR ONE CUBIC YARD MORTAR OR CONCRETE

MIXTURES				QUANTITIES OF MATERIALS			
				Fine Aggregate		Coarse Aggregate	
Cement	F. A. (Sand)	C. A. (Gravel or Stone)	Cement in sacks	cu. ft.	cu. yd.	cu. ft.	cu. yd.
1	1½	....	15.5	23.2	0.86	....	....
1	2	....	12.8	25.6	0.95	....	....
1	2½	....	11.0	27.5	1.02	....	....
1	3	....	9.6	28.8	1.07	....	....
1	1½	3	7.6	11.4	0.42	22.8	0.85
1	2	2	8.3	16.6	0.61	16.6	0.61
1	2	3	7.0	14.0	0.52	21.0	0.78
1	2	4	6.0	12.0	0.44	24.0	0.89
1	2½	3½	5.9	14.7	0.54	20.6	0.76
1	2½	4	5.6	14.0	0.52	22.4	0.83
1	2½	5	5.0	12.5	0.46	25.0	0.92
1	3	5	4.6	13.8	0.51	23.0	0.85

MATERIALS REQUIRED FOR 100 SQ. FT. OF CONCRETE OR MORTAR OF VARYING THICKNESSES

C - Cement in sacks.
F.A. - Fine aggregate (sand) in cu.ft.
C.A. - Coarse aggregate (pebbles or broken stone) in cu. ft.
Quantities may vary 10 % either way depending upon character of aggregate used, No allowance made in table for waste.

Proportion	1 - 1½			1 - 2			1 - 2½			1 - 3		
Thickness in inches	C.	F.A.	C.A.	C.	F.A.	C.A.	C.	F.A.	C.A.	C.	F.A.	C.A.
3/8	1.8	2.7	....	1.5	3.0	....	1.3	3.2	....	1.1	3.4	....
1/2	2.4	3.6	....	2.0	4.0	....	1.7	4.3	....	1.5	4.4	....
3/4	3.6	5.4	....	3.0	6.0	....	2.5	6.3	....	2.2	6.8	....
1	4.8	7.2	....	4.0	7.9	....	3.4	8.4	....	3.0	8.9	....
1-1/4	6.0	9.0	....	4.9	9.9	....	4.2	10.5	....	3.7	11.1	....
1-1/2	7.2	10.8	....	5.9	11.9	....	5.1	12.7	....	4.4	13.3	....
1-3/4	8.4	12.6	....	6.9	13.9	....	5.9	14.7	....	5.2	15.7	....
2	9.6	14.4	....	7.9	15.8	....	6.8	16.9	....	5.9	17.7	....
	1 - 2 - 2			1 - 2 - 3			1 - 2½ - 3½			1 - 3 - 5		
3	7.7	15.4	15.4	6.5	13.0	19.3	5.5	13.6	19.1	4.3	12.8	21.3
4	10.2	20.4	20.4	8.6	17.2	25.8	7.3	18.1	25.4	5.7	17.0	28.4
5	12.8	25.6	25.6	10.8	21.6	32.2	9.1	22.6	31.8	7.1	21.3	35.5
6	15.4	30.7	30.7	12.9	25.8	38.6	10.9	27.2	38.2	8.5	25.6	42.6
8	20.6	41.0	41.0	17.2	34.4	51.6	14.6	36.4	51.0	11.4	34.1	57.0
10	25.6	51.2	51.2	21.5	43.2	64.4	18.2	45.3	63.5	14.2	42.5	71.0

MORTAR MATERIALS REQUIRED FOR CONCRETE MASONRY (8" WALL)

(Note) Amount of mortar required is subject to wide variation, depending upon wastage and how joints are made. The following figures represent general practice on the basis of 25 per cent wastage and 3/8 inch mortar joints, the mortar joints being non-continuous through the wall.

For Ordinary Work: One sack cement, 1 cu. ft. lime and 6 cu. ft. sand will make mortar sufficient to lay up the following: 120 8 by 8 by 16 inch block, or 175 5 by 8 by 12 inch concrete building tile.

For Special Work: One sack cement, 10 pounds lime and 3 cu. ft. sand will make mortar sufficient to lay up the following: 55 8 by 8 by 16 inch concrete block, or, 75 5 by 8 by 12 inch concrete building tile.

Referring to table under 1-2½-3½ mixture for 12 inch walls, 21.8 sacks of cement are required for each 100 sq. ft. of surface. Dividing 924 by 100 gives the number of times 100 sq. ft. are contained in the total wall surface and multiplying by 21.8 gives the total number of sacks of cement required. Similar calculations are made for the fine aggregate and the coarse aggregate in both the wall and the footing, noting that the width of the footing, 18 inches, is 1½ times the 12 inch wall.

$$\frac{924 \times 21.8}{100} = 201.5 \text{ sacks cement}$$

$$\frac{924 \times 54.5}{100} = 503.6 \text{ cu. ft. fine aggregate}$$

$$\frac{924 \times 76.3}{100} = 705. \text{ cu. ft. coarse aggregate}$$

The footing contains 132 sq. ft. of surface, 18 inches thick, (1.5 x 12 inches) deducting for duplication at corners.

$$\frac{132 \times 21.8 \times 1.5}{100} = 43.2 \text{ sacks cement}$$

$$\frac{132 \times 54.5 \times 1.5}{100} = 107.9 \text{ cu. ft. fine aggregate}$$

$$\frac{132 \times 76.3 \times 1.5}{100} = 151. \text{ cu. ft. coarse aggregate}$$

Total materials required for footing and wall: 244.7 sacks cement, 611.5 cu. ft. fine aggregate, 856 cu. ft. coarse aggregate.

Problem II:

What quantities of materials are required for a 1:2 cement plaster coat, one inch thick on the lower three feet of the above foundation?

Solution:

Perimeter of foundation: 4 x 34 feet = 136 feet. This multiplied by height of plaster coat, three feet, equals 408 square feet.

$$\frac{408 \times 4.0}{100} = 16.3 \text{ sacks of cement}$$

$$\frac{408 \times 7.9}{100} = 32.2 \text{ cu. ft. sand}$$

Note: Plans and lists usually will give a list of materials needed for concrete work. No further computations should be necessary unless the peculiarities of the site are such that changes are necessary in the dimensions of walls or footings.

142. Measurement of Materials.

All materials used for making concrete must be accurately measured either by volume or by weight, so that a uniform mixture will be obtained for the entire job.

A. Measurement by Volume.

For hand mixing, a bottomless frame is usually constructed for measuring fine and coarse aggregates. The frame should be accurately constructed to hold 1 cu. ft., 2. cu. ft., or any other convenient volume of material. Water is usually measured in a bucket which has been marked to indicate gallons and half-gallons. Materials are seldom measured by volume if the mixing is to be done by a machine.

The table on page 223 has been conveniently arranged to indicate the volume of materials required for concrete using 1 inch and 2 inch aggregate.

B. Measurement by Weight.

On all large construction jobs and on the smaller jobs where the mixing of concrete is done by machinery, the aggregates are measured by weight. This method gives better control, more uniform results, and greater economy. Before accurate results can be obtained by this method of measuring, tests must be run to determine the moisture content of the aggregate. When this has been done the amount of water contained in the aggregate should be subtracted from the amount for the mix. Materials are usually weighed on a platform scale. The table on page 224 has been conveniently arranged to show the weight of materials required for concrete, using 1 inch and 2 inch aggregate.

143. Mixing Concrete.

Practically all concrete, even for small jobs, is mixed by machinery in batch mixers of various capacities from 2 cu. ft. to 4 cu. yds. per batch. Mixers have been brought to a high state of efficiency and produce satisfactory results at a minimum cost of labor and power. Mixers should not be overloaded nor should they be operated at higher speeds than those recommended by the manufacturer. Small changes in the speed of a mixer have very little effect on the strength of the concrete. The time of mixing influences the strength and quality of the resulting concrete.

Mixing should proceed until all of the particles are completely coated with cement. Various tests have been conducted that show that the minimum time to be allowed for mixing a batch of concrete should be one minute, 15 seconds. Thorough mixing gives increased workability, which in turn requires less labor in placing and is also of great assistance in securing water-tight concrete.

On small jobs where the amount of concrete will not justify the use of a machine mixer, the mixing may be done by hand. This will require a tight floor or mixing platform, which may be constructed especially for that purpose. Hand mixing is usually accomplished as follows:

VOLUME OF MATERIALS REQUIRED FOR CONCRETE

WITH ONE INCH AGGREGATE

Consistency	Materials Per Sack of Cement: With Gravel: Sand cu.ft.	With Gravel: Gravel cu.ft.	With Gravel: Water* gal.	With Crushed Stone: Sand cu.ft	With Crushed Stone: Stone cu.ft.	With Crushed Stone: Water* gal.	Materials Required for One Cubic Yard of Concrete: Cement sacks	With Gravel: Sand cu. ft.	With Gravel: Sand cu. yd.	With Gravel: Gravel cu. ft.	With Gravel: Gravel cu. yd.	With Crushed Stone: Sand cu. ft.	With Crushed Stone: Sand cu. yd.	With Crushed Stone: Stone cu. ft.	With Crushed Stone: Stone cu. yd.
Total Mixing Water 5 Gallons Per Sack of Cement															
Stiff.....	2.1	3.1	3.9	2.5	2.8	3.7	6.6	14.1	.52	20.4	.76	16.6	.62	18.2	.67
Medium	1.9	2.7	4.0	2.2	2.4	3.8	7.2	13.6	.50	19.7	.73	16.0	.59	17.6	.65
Wet.....	1.7	2.4	4.2	2.0	2.2	3.9	7.8	13.1	.49	19.0	.70	15.5	.57	16.9	.63
Total Mixing Water 6 Gallons Per Sack of Cement															
Stiff.....	2.8	3.6	4.6	3.3	3.2	4.2	5.5	15.6	.58	20.0	.74	18.3	.68	17.7	.66
Medium.....	2.5	3.2	4.7	3.0	2.9	4.4	6.0	15.1	.56	19.4	.72	17.7	.66	17.2	.64
Wet.....	2.3	2.9	4.8	2.6	2.6	4.6	6.5	14.6	.54	18.8	.70	17.2	.64	16.6	.62
Total Mixing Water 7½ Gallons Per Sack of Cement															
Stiff.....	3.9	4.5	5.4	4.6	3.9	5.1	4.4	17.2	.64	19.6	.73	20.1	.74	17.2	.64
Medium.....	3.5	4.0	5.6	4.1	3.5	5.3	4.8	16.8	.62	19.0	.70	19.5	.72	16.7	.62
Wet.....	3.1	3.5	5.8	3.6	3.1	5.5	5.2	16.3	.60	18.3	.68	18.9	.70	16.2	.60
WITH TWO INCH AGGREGATE															
Total Mixing Water 5 Gallons Per Sack of Cement															
Stiff.....	2.2	3.7	3.8	2.6	3.4	3.7	6.0	13.3	.49	22.2	.82	15.7	.58	20.2	.75
Medium.....	2.0	3.2	4.0	2.3	3.0	3.8	6.6	13.0	.48	21.4	.79	15.2	.56	19.4	.72
Wet.....	1.7	2.9	4.2	2.0	2.6	3.9	7.2	12.5	.46	20.6	.76	14.6	.54	18.8	.70
Total Mixing Water 6 Gallons Per Sack of Cement															
Stiff.....	3.0	4.3	4.5	3.4	4.0	4.2	5.0	14.9	.55	21.6	.80	17.2	.64	19.6	.73
Medium.....	2.6	3.8	4.7	3.0	3.5	4.4	5.5	14.4	.53	21.0	.78	16.8	.62	19.0	.70
Wet.....	2.3	3.4	4.8	2.7	3.1	4.6	6.0	13.9	.52	20.4	.76	16.3	.60	18.4	.68
Total Mixing Water 7½ Gallons Per Sack of Cement															
Stiff.....	4.1	5.3	5.2	4.7	4.8	5.0	4.0	16.5	.61	21.2	.79	19.0	.70	19.1	.71
Medium.....	3.6	4.6	5.6	4.2	4.2	5.2	4.4	16.0	.59	20.6	.76	18.4	.68	18.6	.69
Wet.....	3.2	4.2	5.8	3.7	3.8	5.5	4.8	15.6	.58	20.0	.74	17.9	.66	18.0	.67

*Corrected for free moisture carried by sand. This table is based on the following assumptions: Absorption of aggregates 1% by weight; free moisture in sand 5% by weight; coarse aggregate surface dry; weight of sand 89 lb. per cu. ft. measured damp, loose; weight of coarse aggregate 99 lb. per cu. ft. measured loose.

WEIGHT OF MATERIALS REQUIRED FOR CONCRETE

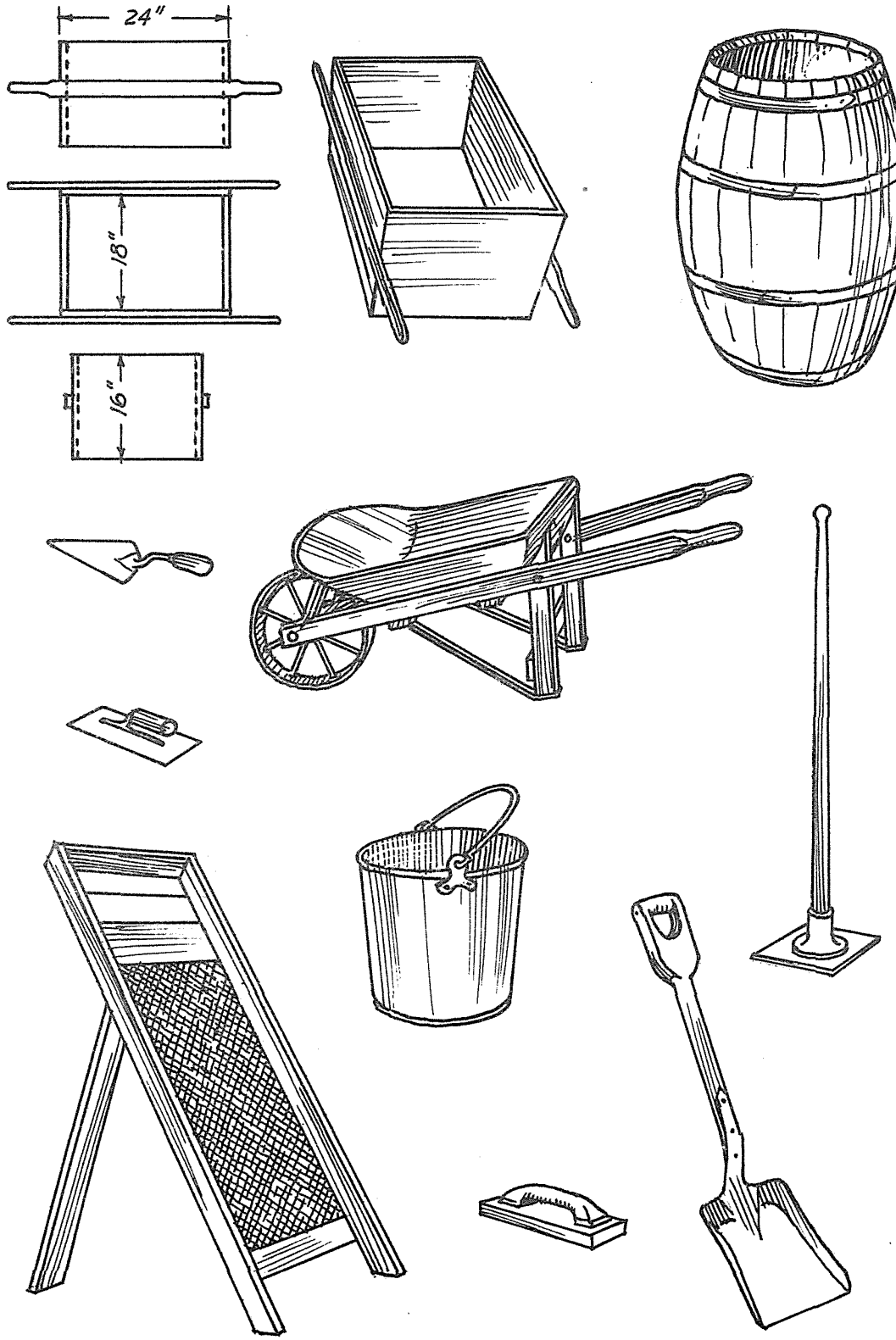
WITH ONE INCH AGGREGATE

Consistency	Materials per Sack of Cement: With Gravel — Sand lbs.	Gravel lbs.	Water gals.	With Crushed Stone — Sand lbs.	Stone lbs.	Water* gals.	Materials Required Per Cubic Yard of Concrete: Cement sacks	With gravel — Sand lbs.	Gravel lbs.	With Stone — Sand lbs.	Stone lbs.
5 Gallons Total Water Per Sack of Cement											
Stiff	189	307	3.9	225	273	3.7	6.6	1250	2025	1480	1805
Medium	167	271	4.0	199	241	3.8	7.2	1200	1950	1430	1740
Wet	149	241	4.2	177	215	3.9	7.8	1160	1875	1380	1670
6 Gallons Total Water Per Sack of Cement											
Stiff	252	360	4.6	297	318	4.2	5.5	1390	1980	1630	1750
Medium	224	320	4.7	263	283	4.4	6.0	1350	1920	1580	1700
Wet	201	286	4.8	236	253	4.6	6.5	1310	1860	1530	1640
7½ Gallons Total Water Per Sack of Cement											
Stiff	350	441	5.4	406	386	5.1	4.4	1540	1940	1790	1700
Medium	312	392	5.6	362	344	5.3	4.8	1500	1880	1740	1650
Wet	278	351	5.8	323	307	5.5	5.2	1450	1820	1680	1600

WITH TWO INCH AGGREGATE

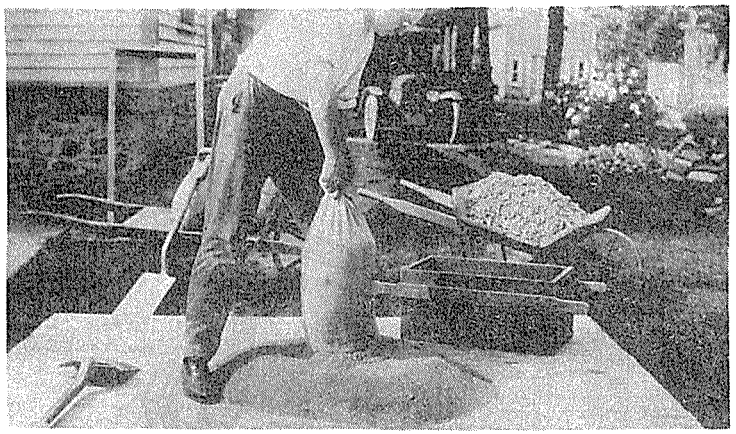
5 Gallons Total Water Per Sack of Cement											
Stiff	199	366	3.8	234	333	3.7	6.0	1190	2200	1400	2000
Medium	175	321	4.0	205	292	3.8	6.6	1160	2115	1350	1920
Wet	155	284	4.2	181	258	3.9	7.2	1120	2040	1300	1860
6 Gallons Total Water Per Sack of Cement											
Stiff	266	428	4.5	307	398	4.2	5.0	1330	2140	1540	1940
Medium	234	378	4.7	272	342	4.4	5.5	1290	2080	1500	1880
Wet	208	336	4.8	241	304	4.6	6.0	1250	2020	1450	1820
7½ Gallons Total Water Per Sack of Cement											
Stiff	369	525	5.2	424	473	5.0	4.0	1470	2100	1690	1890
Medium	325	464	5.6	373	418	5.2	4.4	1430	2040	1650	1840
Wet	290	413	5.8	332	372	5.5	4.8	1390	1980	1600	1780

*Amount of water to add allowing for moisture in sand. This table is based on aggregates of 2.65 specific gravity and sand containing 5% moisture by weight. No allowance has been made for waste.

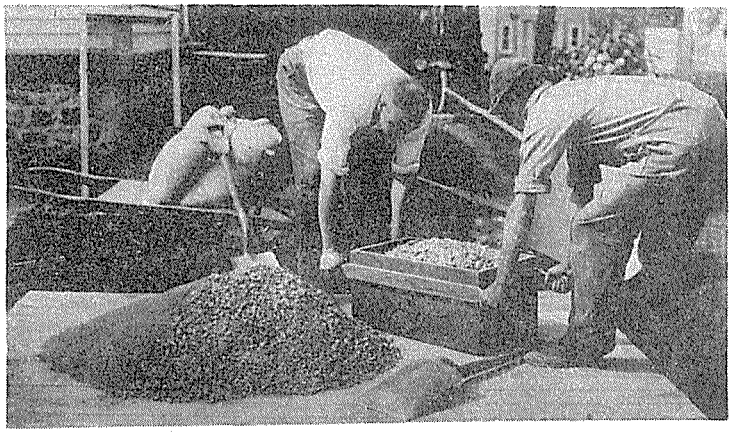


COURTESY OF PORTLAND CEMENT ASSOCIATION

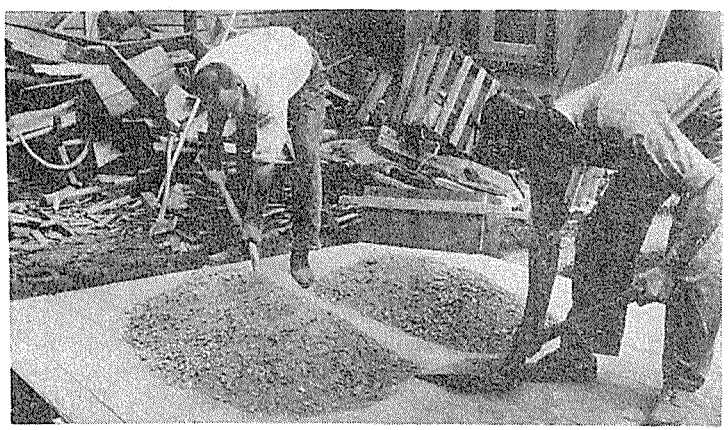
EQUIPMENT FOR HAND MIXING



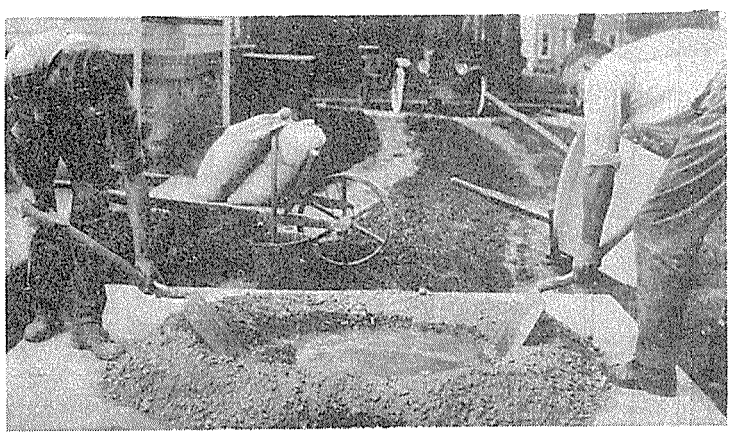
Add Cement to proper amount of sand



Measure Pebbles or Crushed Stone



Mix the dry Materials



Use Minimum amount of Water

COURTESY OF PORTLAND CEMENT ASSOCIATION

HAND MIXING METHODS

The amount of sand required for the batch is first poured on the platform and then spread out evenly. The necessary amount of cement is distributed over the sand. The two materials are then turned with square pointed shovels, at least three times, or until the combined mixture is uniform in color. The sand-cement mixture is then spread out and the required amount of gravel is spread over the top. The materials are again thoroughly turned by shovels until the whole mass is again uniform in color. A hollow depression is then formed in the center of the pile and the exact quantity of water required for the mix is poured into this depression. The material in the pile is then gradually turned into the water with the shovels and thoroughly mixed until the resulting concrete has the same color and plasticity throughout.

144. Transporting Concrete.

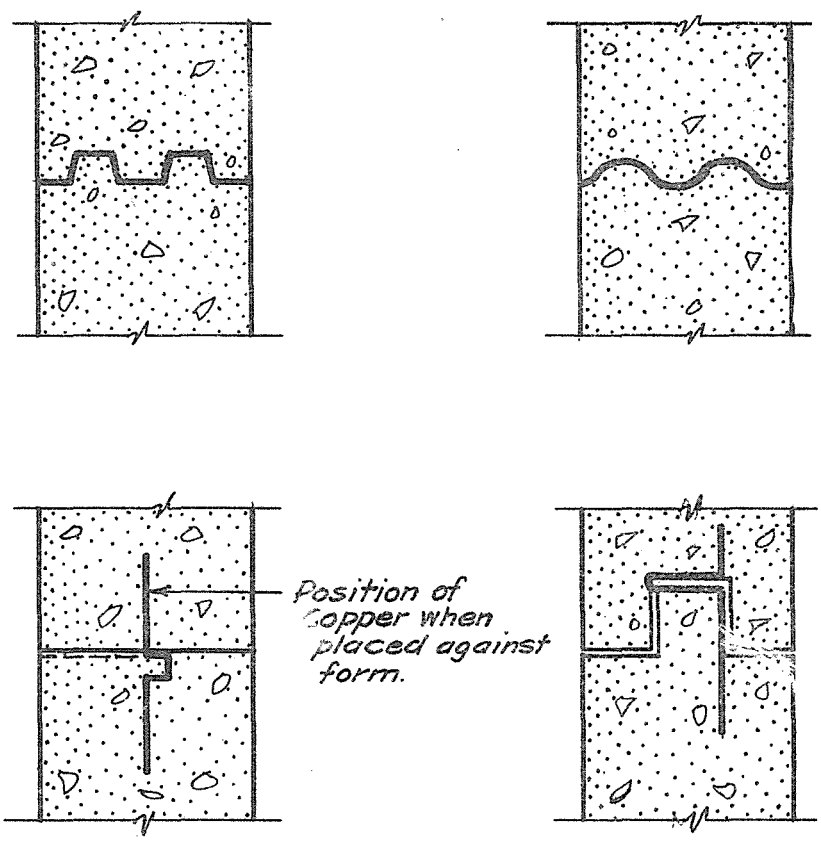
The method of transporting concrete from the mixer to the forms is primarily a question of economy. The method selected must not interfere with the delivery of concrete of the proper quality and uniformity. For this reason, the design of the mix may be governed largely by the type of equipment to be used. On small jobs the concrete may be economically conveyed by wheelbarrows or buggies, but on large jobs it is usually more economical to use hoist towers or chutes.

Hoist towers are generally located near to the mixer. The concrete is usually lifted to the proper level by endless chain buckets, constructed inside the tower. In some instances the concrete is dumped into buggies at the mixer and they are transported by the hoist to the proper elevation, from which they are wheeled to the forms.

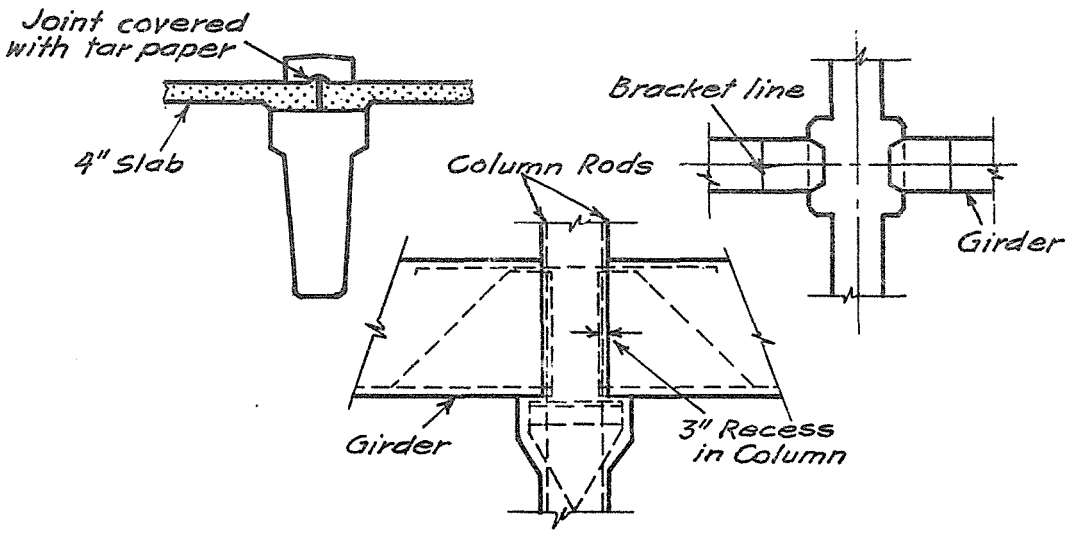
Chutes may be used from the mixer to the forms for the lower levels or from the hoist tower to the forms at higher levels. The chute should have a slope not flatter than 1 to 3, nor steeper than 1 to 2. The mix to be chuted should be so designed that the concrete will travel fast enough to keep the chutes clean, but not so fast that the materials will segregate. Chutes must be kept clean by thorough flushing after each run, but the water used for flushing should not be allowed to discharge into the concrete in the forms.

145. Placing Concrete.

The most important step in concrete construction is that of placing the concrete in the forms. All debris, chips, and shavings, should be removed from within the forms and from the sides of the forms and they should be thoroughly wetted or oiled immediately preceding the pouring of the concrete. Concrete for slabs should be deposited in layers of equal thickness over the entire area. The pouring area should not be so large that subsequent layers cannot be placed before the previous layer has attained its initial set. Beams or girders should be poured in the same way as slabs. Columns should be poured in one operation to the bottom of the beam or the floor slab which it is to support.



EXPANSION JOINTS FOR VERTICAL LOADING



EXPANSION JOINTS

Two-way slab bridges should be poured in two sections because a narrow strip can be given a better finish than an extremely wide one. Construction joints between the two sections should be built according to the plans and specifications. Deck girder type bridges should be poured in alternate sections.

A. Prevention of Segregation.

Constant supervision is essential to prevent segregation of the materials when the concrete is received in the form. The material should be of such consistency that it will flow properly into the corners and angles of the forms and around the reinforcement. Concrete must not be dropped more than three or four feet. The common practice of depositing concrete at one point and allowing it to flow to distant points should be discouraged. Flowing over long distances will cause segregation of the water and fines from the rest of the mass. An excessive amount of tamping or puddling in the forms will also tend to cause the materials to separate. When concrete is properly proportioned the entrained air will escape and the mass will be thoroughly consolidated with very little puddling. Light spading of the concrete next to the forms will prevent honey-combing and make surface finishing easier. When concrete is placed in deep layers the increased pressure on the lower portions will tend to produce a gradual increase in the water content of the upper portion. The excess water should be worked to a low point and removed.

B. Prevention of Laitance.

Laitance can only form from the presence of excess water. This means that the upper portion of concrete on which laitance has formed will be porous and the removal of a small layer of laitance will still leave a layer of porous concrete through which water will pass even under moderate pressure. Laitance can be prevented by the removal of the excess water at the end of each day's work.

C. Vibration.

Vibrators are used for placing and consolidating concrete. With their use it is possible to make concrete flow through small openings in and around closely spaced reinforcement and into other places where it is difficult to secure good results by hand placing. Vibrators are usually attached to the forms or to a heavy plank or shoe placed on top of the freshly deposited concrete. On some jobs automatic vibrators are not used but the forms are shaken by tapping lightly with sledge hammers. Vibration does not affect the strength of concrete but when it is sufficiently intense to be effective it permits the use of stiffer mixtures and lower sand content and thus allows the use of either less water or a leaner mix. It is thus possible to produce higher strength concrete with a given mix by reducing the amount of water required for placing.

146. Curing Concrete.

Concrete hardens because of the chemical reaction between Portland Cement and water. The process continues indefinitely, so long as

the temperatures are favorable and moisture is present to complete the hydration. The quality of concrete is dependent upon its age and the conditions under which it is cured. In extremely cold weather fresh concrete must be protected to prevent freezing until it has properly set. During hot weather fresh concrete should be protected by some form of covering which must be kept continuously wet for at least 10 days.

Thorough curing is one of the most important elements in the production of water-tight concrete. The most effective and economical method of making it impervious to water is to build up the internal structure of the concrete through complete hydration of the cement. The necessity for proper curing of retaining walls, tanks, and other structures subject to hydrostatic pressure, or severe weather, cannot be under-estimated.

Abrasive resistance is also increased by proper curing. Continuous damp curing, particularly in the early stages of hardening, aids in securing a hard, dense surface, and in preventing checking and dusting. The moisture should be applied soon enough to prevent the surface from drying out and shrinking before the concrete has hardened.

Practically all concrete contains an excess of water over that required for hydration. The problem of curing is to prevent the evaporation of this water. In some cases the surface of the concrete is sealed with a compound which is applied immediately after it has set. This is effective where the sealing of the surface may be accomplished without penetration. In many instances, burlap, canvas, straw, or earth is placed on the concrete as soon as possible without marring the surface, and is immediately wetted down. Large horizontal surfaces, such as floors and pavements may be cured by ponding. This may be accomplished by surrounding the surface to be cured with small earthen dikes and then keeping the surface flooded with water for the required period. All exposed surfaces should be protected from drying out for at least 7 days and for a longer period if practicable.

147. Samples for Tests.

On all concrete construction jobs where the work continues for more than two days, occasional tests should be made to determine the effectiveness of the field control of concrete. These tests should be made in accordance with the A.S.T.M. serial designation C-31-33, entitled "Standard Method of Making and Storing Specimens of Concrete in the Field." This may be secured from the Portland Cement Association.

148. Cold Weather Construction.

Construction operations are now carried on throughout the year with very little interruption due to cold weather. If proper precautions are taken the same quality of concrete may be produced in cold weather as is produced in warm weather. If construction work is to continue during the winter months a definite plan should be outlined against freezing. All necessary equipment and material for carrying out the plan should be on the ground before the work is started. The

aggregates may be kept free from frost by heating with steam pipes in the storage bin or by heating over a fire just previous to placing them in the mixer. The mixing water should be heated before being used.

Forms containing green concrete may be protected by canvas enclosures which are heated. Protection should continue until the end of the freezing weather or until the concrete has properly set. If the weather is not too extreme the only protection that is necessary may be a coverage of straw, dry earth, or dry sand.

149. Removal of Forms.

Concrete forms should not be removed until the concrete has become thoroughly hard. The time required for hardening cannot be definitely set because it depends upon the kind of work being done and upon local temperature and weather conditions. The average minimum time for removal is usually set at three days. Forms which are used on the under side of floors and beams should be left in place for from two to four weeks. Care should be exercised to prevent chipping corners during removal of the forms.

After form boards are removed, they should be thoroughly cleaned and covered with a coat of light oil and piled so that they will dry out without warping.

150. Finishing.

The surface of concrete may be finished in any number of ways depending upon the use to which it is to be put. Foundation walls and the parts of bridges and culverts which are to be covered are usually finished only by filling the holes left by form wires and by honeycombing. Where the faces of walls are exposed to view the finish is carried a little farther. The rough spots are usually honed off and the entire surface is given a wash finish of neat cement. Some structures are given tooled finishes to imitate stone masonry.

Floors and pavements are always finished while the concrete is still pliable. This finish usually consists of screeding, floating and troweling. Screeding means moving a straight edge over the top of the poured concrete to strike off the finish at the right level. A slight compaction occurs during this operation. The hollows in the surface are filled up and the humps ironed out by floating the surface with a wood or cork float. This tends to drive the larger particles to the bottom and cause the fines to rise to the top. The final operation is troweling, either by wooden or metal trowels. Wood trowels usually give a little rougher finish than metal trowels.

Floor surfaces are sometimes given a granolithic finish by the application of granite or marble chips to the surface of the floor just before the final troweling. Excessive use of a trowel should be avoided.

151. Concrete Floors.

Concrete floors are classified according to the way in which they are built. Monolithic floors are the most common. They are constructed in such a manner that the top and base set together to form one solid piece. The usual procedure is to pour the base and allow it to set for an hour or two and then pour a finish coat over it. Quite often the finish coat is not applied but the base is floated and troweled until the required surface is obtained.

In certain types of construction the "base and topping" method is used, where the base course is poured and left with a roughened surface. It may be days or weeks before the final coat is placed and the surface finished to its final state. One advantage of this type of construction is that the final floor surface escapes all of the abrasion incident to construction operations. There is, however, a distinct disadvantage, which is that the top course may become loose and chip off unless it is properly bonded to the base.

Floors built by the base and topping method may be given any one of a great variety of finished surfaces. The most common surface is that made with plain cement and sand. In some cases the mortar is colored by the addition of pigments, while in other cases a granolithic finish is given to the floor by the addition of fragments of granite or marble not larger than 3/8 inch. The use of quick setting cement is quite general in the construction of floors of this type.

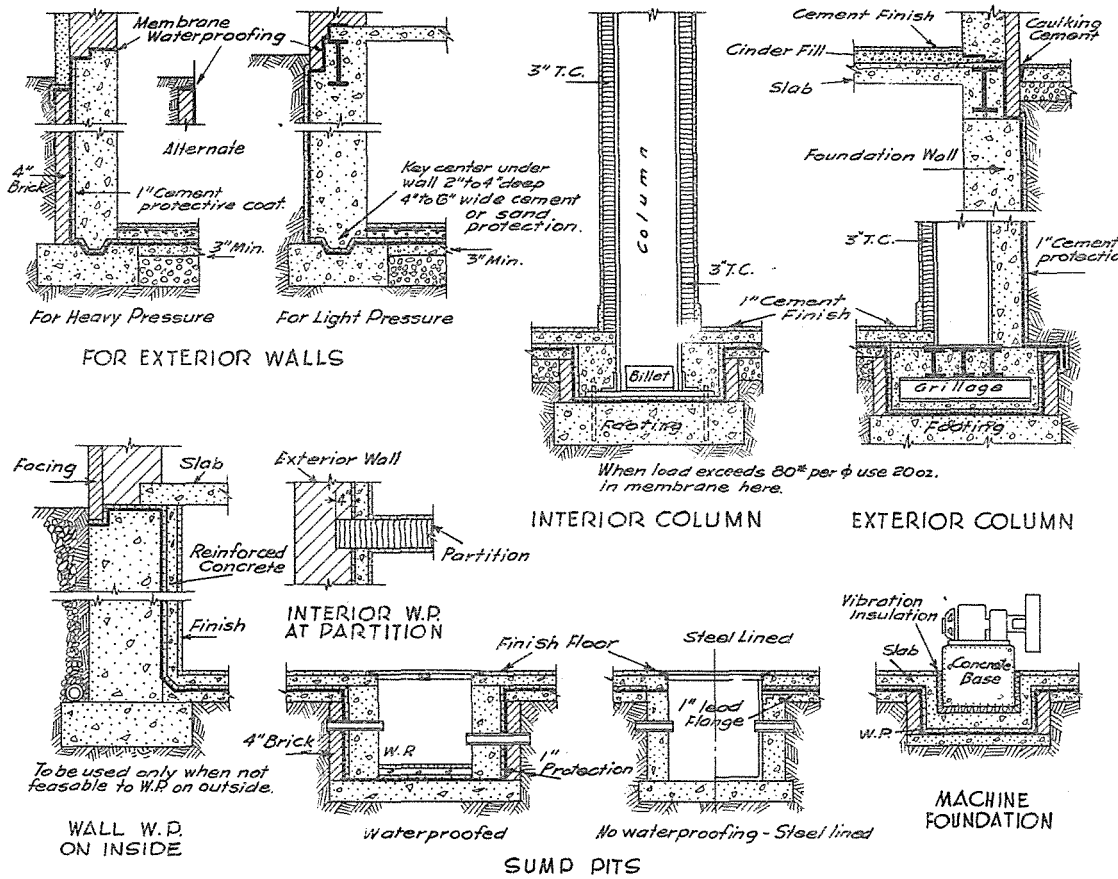
152. Placing Concrete Under Water.

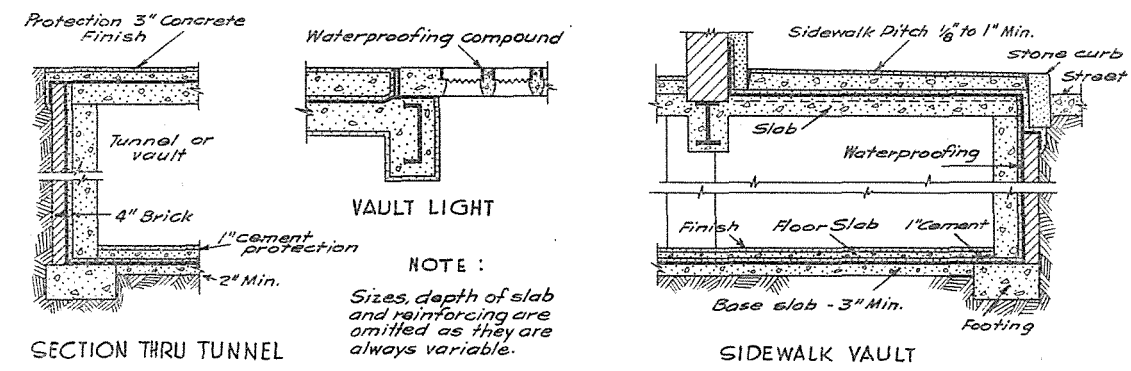
There is always some uncertainty as to the results obtained from placing concrete under water, and it should not be done if it is practicable to deposit it in the dry. Expert supervision is necessary for this work and every precaution must be taken to prevent the cement from being washed out of the concrete. The formation of laitance should be avoided, but if it is impossible to avoid, it should be removed.

One successful method of placing concrete under water has been with the tremie. This is usually a steel pipe or tube long enough so that the lower end will reach the bottom of the work when the upper end is above the water level. The upper end is usually provided with a hopper to receive the concrete. The lower end is plugged to prevent the entrance of water and the escape of the concrete. The tremie is filled with concrete and lowered into position. When the lower end reaches the bottom of the work the plug is removed and the concrete is allowed to flow out slowly. As concreting proceeds, the lower end of the tremie should be kept submerged in the concrete, only raising and moving it enough to cause the concrete to flow into place. The tremie should be kept constantly full of concrete during the operation.

153. Repairing Broken Concrete.

It is sometimes necessary to restore broken corners of walls or foundations. The usual method employed is to slightly roughen the surface under the break and then fill out the hole with new cement.





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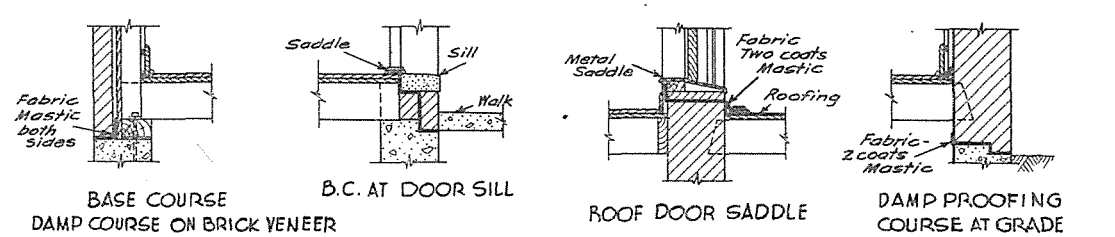
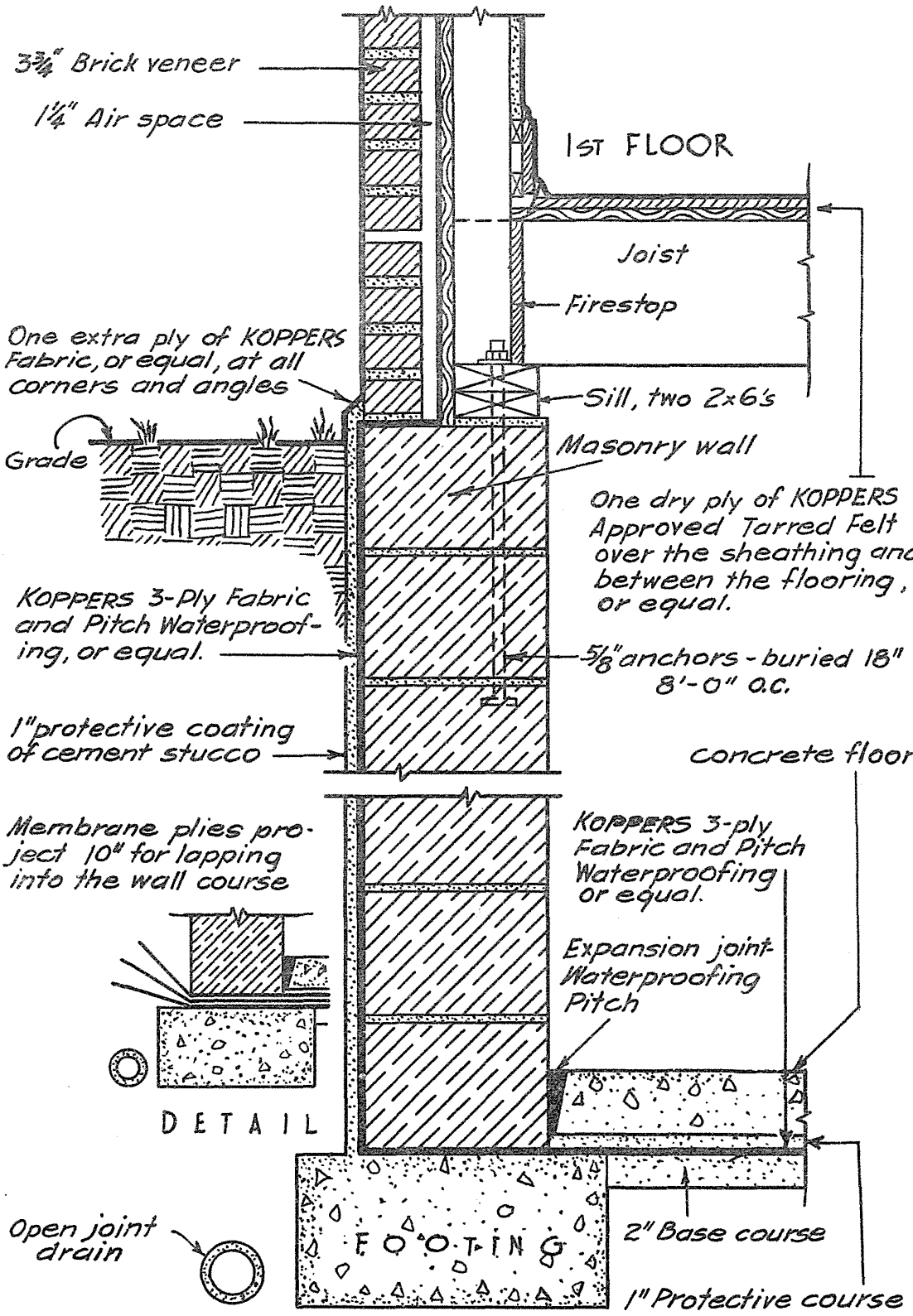
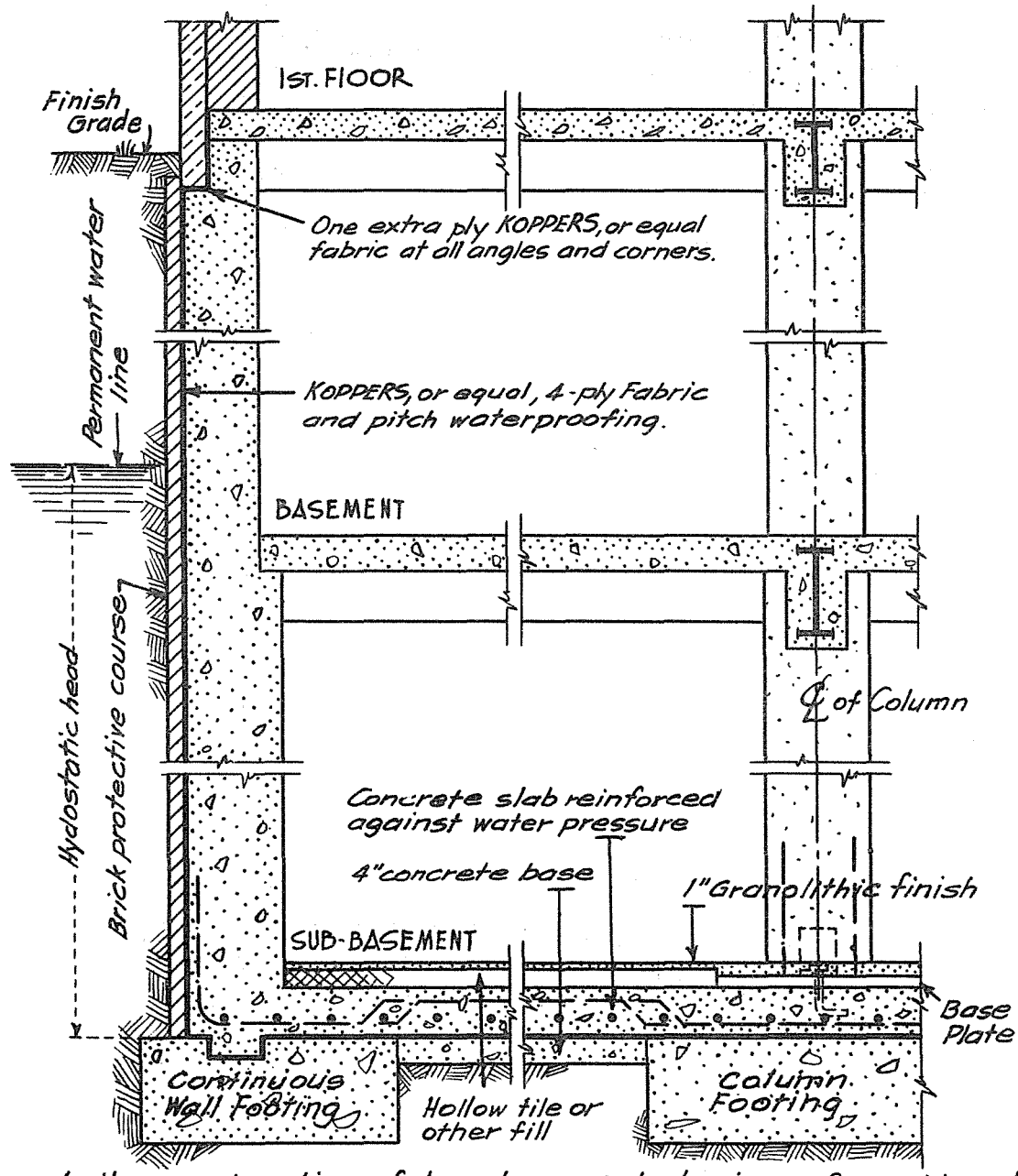


WATERPROOFING


3¾" Brick veneer
1¼" Air space
1ST FLOOR
Joist
Firestop
One extra ply of KOPPERS Fabric, or equal, at all corners and angles
Sill, two 2x6's
Grade
Masonry wall
One dry ply of KOPPERS Approved Tarred Felt over the sheathing and between the flooring, or equal.
KOPPERS 3-Ply Fabric and Pitch Waterproofing, or equal.
⅝" anchors - buried 18" 8'-0" o.c.
1" protective coating of cement stucco
concrete floor
Membrane plies project 10" for lapping into the wall course
KOPPERS 3-ply Fabric and Pitch Waterproofing or equal.
Expansion joint-Waterproofing Pitch
DETAIL
Open joint drain
FOOTING
2" Base course
1" Protective course

COURTESY OF DON GRAF

WATERPROOFING OF FOUNDATIONS

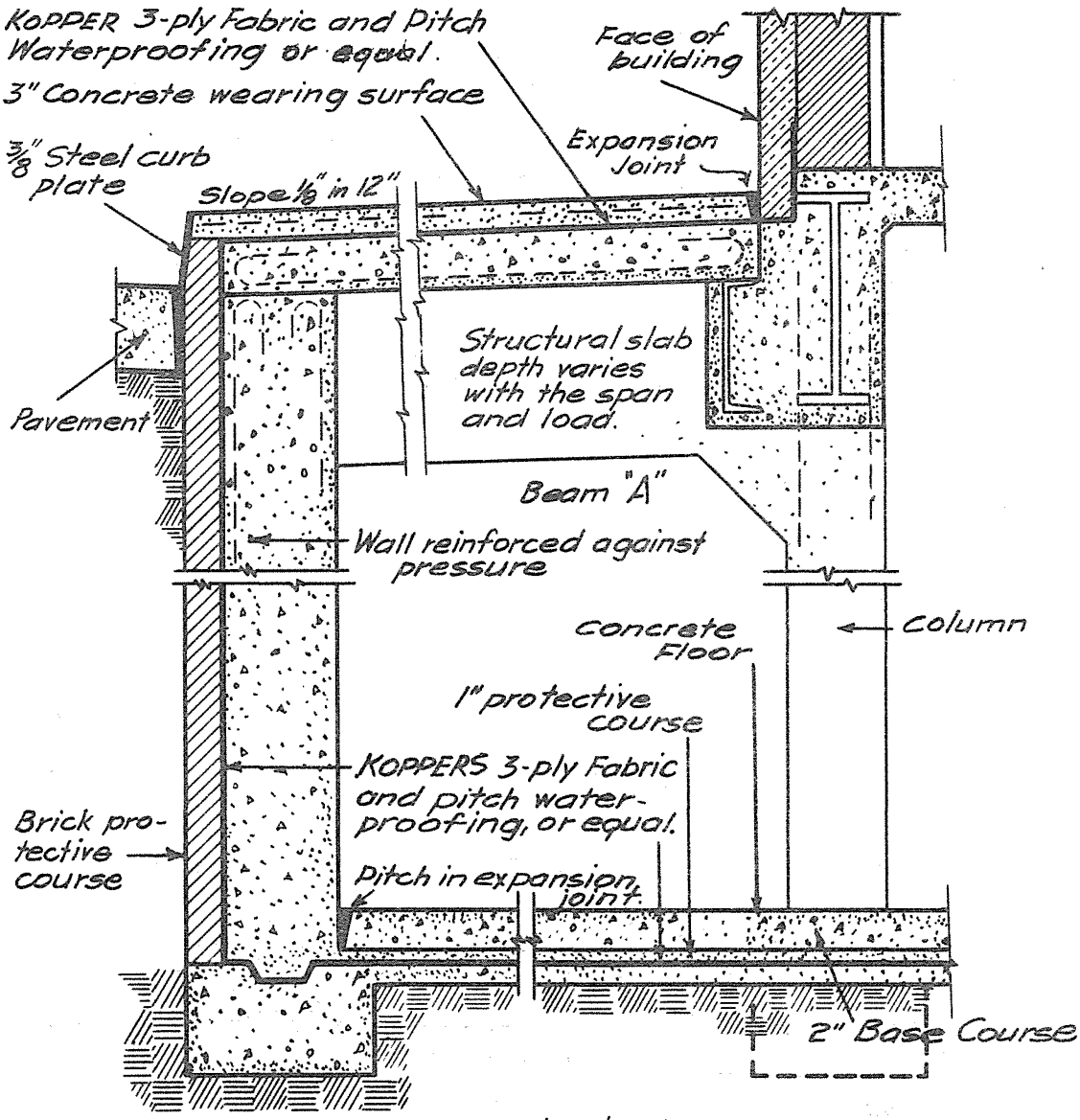


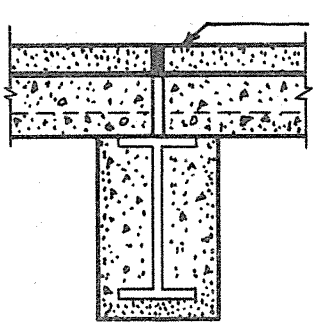
In the construction of deep basements having unfavorable water conditions, the waterproofing method is shown here. KOPPERS, or equal, 4-ply Fabric and Pitch Waterproofing will withstand a hydrostatic head up to 18'. From 18' to 25', 5 plies are used. A sheet of 20-oz. soft rolled copper should be placed between the piles beneath all columns, posts or walls under which the pressure exceeds 400 lbs. per sq. inch.

The sub-basement floor is reinforced as a flat slab to resist the upward pressure of the water. Inverted beams may be used, but these necessitate a greater amount of fill to bring the construction to a level to receive the wearing surface. If piles are used, the footings shown above become the pile cappings. No dowels need be run through the membrane.

COURTESY OF DON GRAF

WATERPROOFING OF DEEP FOUNDATIONS



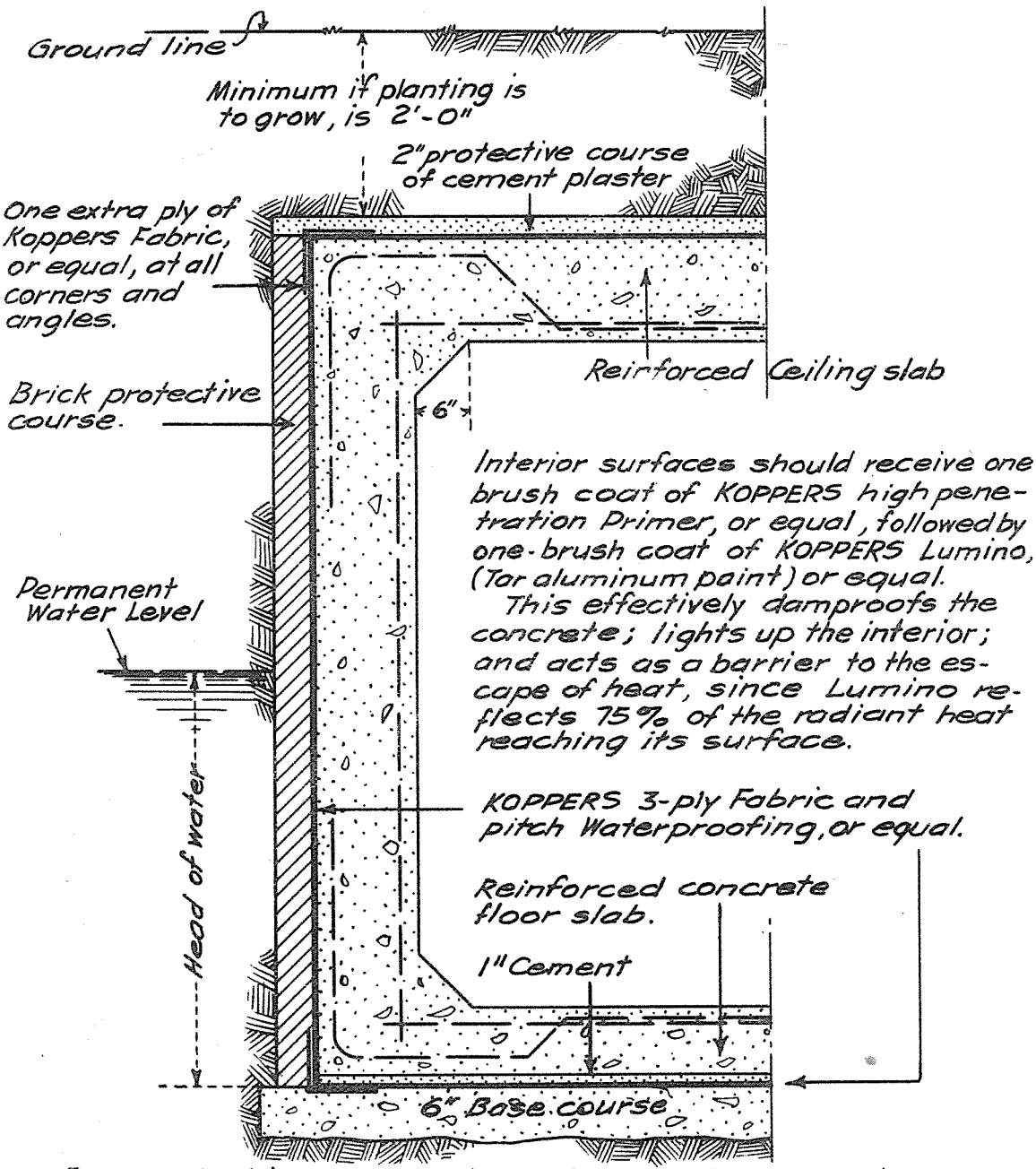


SECTION THRU BEAM "A"

The problem involved in constructing sidewalk vaults is to provide for movement of the concrete to eliminate cracking, and at the same time to exclude water so that the space may be usable. A "1" expansion joint should occur at the building line as shown. Others should occur at proper intervals at right angles to the building face as shown in the detail at left. The membrane acts as a flexible dam in the joint, retaining the filling of pitch. To facilitate the movement of the slabs, 2 dry plies of KOPPERS approved tarred felt, or equal, are placed between the bottom of the slab and its bearing surface on beams or wall, thus breaking the joint.

COURTESY OF DON GRAF

WATERPROOFING OF SIDEWALK VAULT

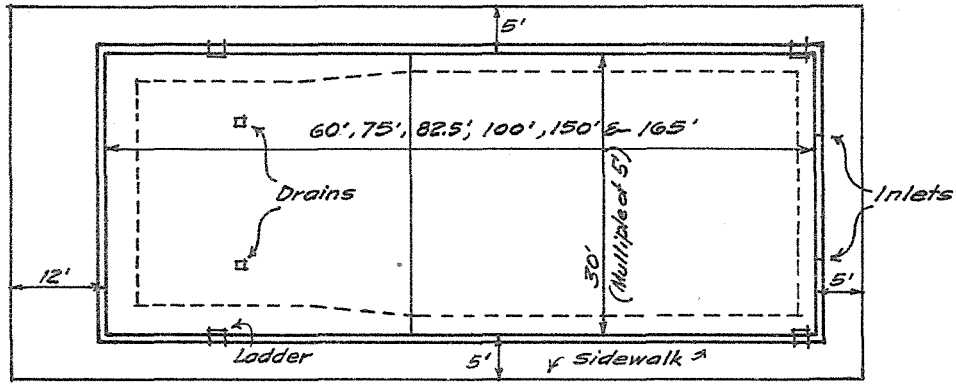

Ground line
Minimum if planting is to grow, is 2'-0"
2" protective course of cement plaster
One extra ply of Koppers Fabric, or equal, at all corners and angles.
Reinforced Ceiling slab
Brick protective course.
6"
Interior surfaces should receive one brush coat of KOPPERS high penetration Primer, or equal, followed by one-brush coat of KOPPERS Lumino, (Tor aluminum paint) or equal.
This effectively damproofs the concrete; lights up the interior; and acts as a barrier to the escape of heat, since Lumino reflects 75% of the radiant heat reaching its surface.
Permanent Water Level
KOPPERS 3-ply Fabric and pitch Waterproofing, or equal.
Head of water
Reinforced concrete floor slab.
1" Cement
6" Base course

Frequently it is necessary to construct subterranean tunnels from one building to another, either for a passageway for circulation of people, or as a conduit to contain pipes and ducts. If the soil will retain ground water or if the passage extends below the permanent water level, an effective waterproofing is necessary as shown above. This forms an unbroken envelope through which moisture is unable to penetrate.

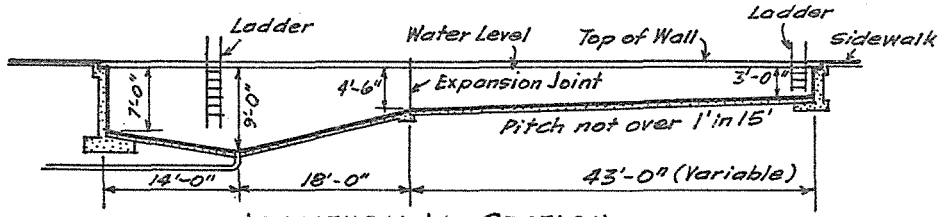
The thickness of the floor slab and the reinforcing will depend upon the span and the head of water to be resisted. The thickness and reinforcing of the walls depend upon the height and the waterhead. The detail of the roof or ceiling slab will depend upon the span and the weight of earth to be sustained.

COURTESY OF DON GRAF

WATERPROOFING SUBTERRANEAN TUNNELS



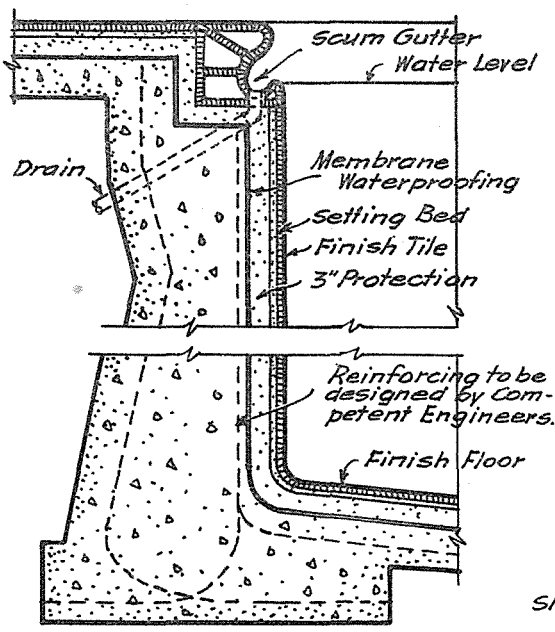
PLAN



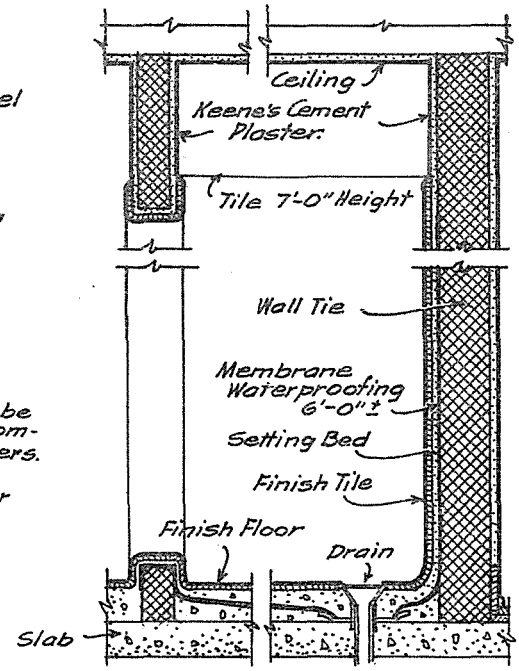
LONGITUDINAL SECTION

30' x 75' SWIMMING POOL

Inside Pools, membrane Waterproofing carried up wall 5' to 6'.



SWIMMING POOL



SHOWER STALL

WATERPROOFING

This method is not very successful because the new piece usually loosens and drops off. The most practical method of restoration is to chip out a series of depressions in the old concrete and drill dowel pin holes in the bottom of each depression. The old concrete is then thoroughly soaked with water and steel dowels are inserted in the holes and set in cement mortar. The new patch should not be applied for at least two days after the dowel pins are set. If the concrete in the patch is made in the same proportions as the concrete in the original wall, unequal shrinkage may be avoided and the restoration will appear no different than the original.

154. Water-tight Concrete.

The importance of water-tightness in a concrete is not reflected alone in its ability to defeat the passage of water. Water-tightness also establishes the durability of the concrete and its ability to resist the action of any liquid or other substance that may come in contact with it. The binding medium which holds the aggregates together must be water-tight. The requirements of water-tight concrete are impervious aggregates thoroughly incorporated in a cement-water paste which is itself impervious.

Every effort should be made to secure a properly designed concrete mix so that it will not be necessary to use admixtures to prevent leakage. It is often desirable to take further precautions against the entrance of water through concrete. One successful method of water-proofing is the use of a strong water-proof blanket on the outside of a wall. This blanket is built up of layers of fabric or felt which are coated and cemented together with hot pitch. It is sometimes necessary to construct a basement in localities where the water table is very near to the ground. The walls and floor should then both be water-proofed in addition to the careful selection of the mix of the concrete. Good results have been obtained by the use of the previously mentioned water-proof blanket on the outside and by the following method of water-proofing the floor:

A 2 inch concrete subfloor
A layer of water-proofing asphalt
A layer of asphalt-covered felt
A layer of water-proofing asphalt
A final topping of concrete

A number of materials are used to stop leaks which appear in finished concrete. Alum, washing soda, waterglass, or calcium chloride are often added to neat cement and applied over the surface of walls in an effort to stop leaks which have appeared. All of these materials are effective, but it is often necessary to make more than one application before the leak is stopped.

References:

Publications of the Portland Cement Association
Pencil Point Data Sheets
Regional Publications.

CHAPTER XV - BUILDING MATERIALS - SELECTION AND USE

155. General.

The use of stone, brick, adobe, tile, tile flue lining and terra cotta may be proper for some purposes and where the policy regarding the use of wood is not violated. Data concerning their selection and use are given so that these materials may be safely selected.

156. Stone.

Stone is generally adaptable to buildings and structures. Many jobs can be made to harmonize with natural settings by its use. Stone may be used for foundations, piers, retaining walls, abutments, walks, walls and chimneys. It should be selected with the idea of securing jobs of more or less informal character. Tooled, squared or sized stone seldom has any real place in Forest Service work. The harder sandstones, granite, quartz, etc., laid according to acceptable standards, will prove satisfactory. These can offer much variety and utility in their use. It should not be forgotten that very few natural stones withstand the action of sudden changes in temperature. Stone should be used with discretion in fire-resistant building construction. Granite will explode and disintegrate into sand when exposed to severe heat. Limestones and marbles are usually destroyed by ordinary fire.

157. Brick.

Bricks are usually made of clay and are molded or pressed into shape and then burned in a kiln at a temperature of 2000° F for several days. Their use offers good protection from dampness and from extreme temperatures. They are very resistant to fire, and even the common brick will stand exposure to fire for a considerable length of time.

Clay brick for building purposes is manufactured in accordance with Standard Specifications, C-62-30, of the American Society for Testing Materials, in three grades, based on strength requirements. Sizes of brick are fixed by these standards, with a permissible variation of plus or minus 1/16" in depth, 1/8" in width and 1/4" in length.

Grades of Clay Building Brick

Name of Grade	Compressive Strength (Brick Flatwise) lbs. per sq. in.	Modulus of Rupture (Brick Flatwise) lbs. per sq. in.
	Individual minimum	Individual minimum
Grade A	3500	400
Grade B	2000	300
Grade C	1000	200

Sizes of Clay Building Brick

Type	Depth inches	Width inches	Length inches
Common Brick	2-1/4	3-3/4	8
Rough Face Brick	2-1/4	3-3/4	8
Smooth Face Brick	2-1/4	3-7/8	8

Bricks used for facing in walls, chimneys or fireplaces should be chosen so that they will fit into the final color scheme, or so that they may be painted to match or harmonize therewith. Federal Specification SS-B-656 must be used for the selection of building brick.

A. Fire Brick.

Fire bricks are made of a mixture of silicates and clay. They fuse at a temperature of 3100° F. The standard size is $2\frac{1}{2}$" x $4\frac{1}{2}$" x 9". Fire brick should be used for those parts of a fireplace which will be exposed to a flame. The bricks should be placed flat with a thin joint of fire clay.

B. Adobe Brick.

The adobe used for making brick must be composed of the best clay locally available. It must be free of lime and organic matter. The water used for mixing the adobe should be equal in quality to that used for domestic purposes and must be entirely free from any trace of lime. A small quantity of sodium carbonate must be added to each batch as it is mixed. Mixing and puddling should be done thoroughly.

A small amount of straw should be added to the adobe mix, and it should then be placed in molds and thoroughly compacted to form bricks of uniform size and shape. There should be a minimum of irregularity in the size of the adobe bricks after a sufficient period of drying in the sun.

Adobe bricks should test at least 400 lbs. per sq. in. in compression and 68 lbs. per sq. in. in tension. The safe working strengths may then be taken as 70 lbs. per sq. in. in compression and 11 lbs. per sq. in. in tension.

Adobe bricks must be handled with extreme care to prevent breakage. Only carefully selected and thoroughly seasoned, colored and dried adobe bricks are to be used. An emulsified asphalt can be added to the adobe soil as a stabilizer to make stronger bricks. Adobe bricks thus made are resistant to rain and capillary water after they are thoroughly dried. The permanence imparted by such a stabilizer insures against deterioration which characterizes ordinary adobe construction.

158. Structural Clay Tile.

Hollow clay masonry units are variously called structural terra cotta, structural building blocks, and hollow tile. Units having cells or voids greater than 25% of the gross cross-sectional area are known as structural clay tiles. These are formed into the various commercial shapes by a mechanical extrusion of the plastic clay mass through special dies. The molded shapes are then cut by wires into units of the desired lengths before they are burned.

Three classes of structural clay tile are manufactured from surface clay shale, fire clay or admixtures thereof, conforming to standard specifications and tests of the American Society for Testing Materials. The load bearing value of wall tile based on strength and absorption varies in individual tile from a minimum of 700 lbs. per sq. in., to a maximum of 1400 lbs. per sq. in. in compressive strength based on the gross area. The weight of the tile will vary considerably because of the varying sizes. Tiles will usually weigh from 9 to 55 pounds each. Tiles serve for walls above grade where extreme bearing strength is not required, or for partitions in buildings where plaster surfaces are to be applied.

159. Fire Clay Flue Lining.

Fire clay flue linings are manufactured in much the same manner as structural clay tile. Flue linings are used in Forest Service buildings and structures as an extra precaution against fire. The linings serve as a fire resistant material, and also cover many joints in ordinary masonry chimney construction. Possible joint failure in chimney construction is thus minimized. All brick or stone chimneys should have fire clay flue linings from a point one foot below the lowest thimble opening to the top of the chimney.

160. Terra Cotta.

Clay products which are shaped into forms and baked at a high temperature in special kilns are of two general types, which are called terra cotta and structural clay tile. Terra cotta is also known as architectural or ornamental tile. It is well adapted to the architectural treatment of a fire resistant building. The shells and webs must be proportioned properly and made heavy enough to resist expansion and contraction stresses. The tile must be of sufficient strength to support its share of the wall load as well as its own weight when it is incorporated in a wall.

Special details are required for the design of terra cotta work. Drawings should be made to an exact scale and should show how the pieces are to be assembled, and the means of fastening them in place. Terra cotta pieces should be planned so they will all be of nearly the same size. This will keep the shrinkage factor more or less uniform between pieces and facilitate handling and storage.

CHAPTER XVI - MASONRY AND BRICK CONSTRUCTION

161. Materials Used for Mortars.

A. Hydrated Lime.

Hydrated lime which is used for mortar must be an approved brand complying with Federal Specification SS-L-351, type M, for masonry.

B. Cement.

Cement used in the work must be an approved standard brand of Portland Cement, complying with Federal Specification SS-C-191a and the rules of the Portland Cement Association.

C. Sand.

Sand should be well-graded and must comply with Federal Specification SS-A-281, for Class 1, Grade A aggregate. Tests for determining the sand are given in Article 137.

D. Special Mortars.

Special mortars for masonry are available and may be used where they will serve better than mortars mixed with basic materials. Reference should be made to Federal Specification SS-C-181.

162. Stone Masonry.

A. Stone.

Except for monumental or strictly formal structures, the stone which is used should be native to the area. Besides the convenience and economy of this, the building will harmonize with other structures near it. The final appearance of all stone masonry is based largely upon the material itself. The kind and quality of stone, its cleavage, normal size, shape, surface and color, determine the type of masonry to be used.

The hard, heavy, coarse-grained stones, like quartz and granite, are usually finished with a rough surface, while the finer-grained ones, like limestone, sandstone and marble, have smooth dressed surfaces. In no case should several types of stones be used in the same wall surface.

B. Rubble Masonry.

Rubble masonry is simple in character, and is especially satisfactory for use in simple, intimate, rustic, everyday structures, in

which excellent effects can be obtained by ordinary masons working under the proper supervision. For these reasons, and because it is the most economical type of stone masonry, any one of the several varieties of rubble masonry is satisfactory for Forest Service construction.

Rubble masonry consists of stones which are broken up and only roughly dressed with a hammer before being fitted in place. The kinds of rubble masonry are dependent upon the way the stones are laid. Coursed rubble means that stratified undressed stone is laid in level beds. If the stratified stones are laid on level beds in courses which are broken at intervals, the resulting masonry is called broken range random rubble. Random coursed rubble means that the stratified stones are brought to level beds at varying vertical intervals. When stones of various sizes and shapes are laid without particular regard to the direction or width of joints, the result is known as random rubble or mosaic.

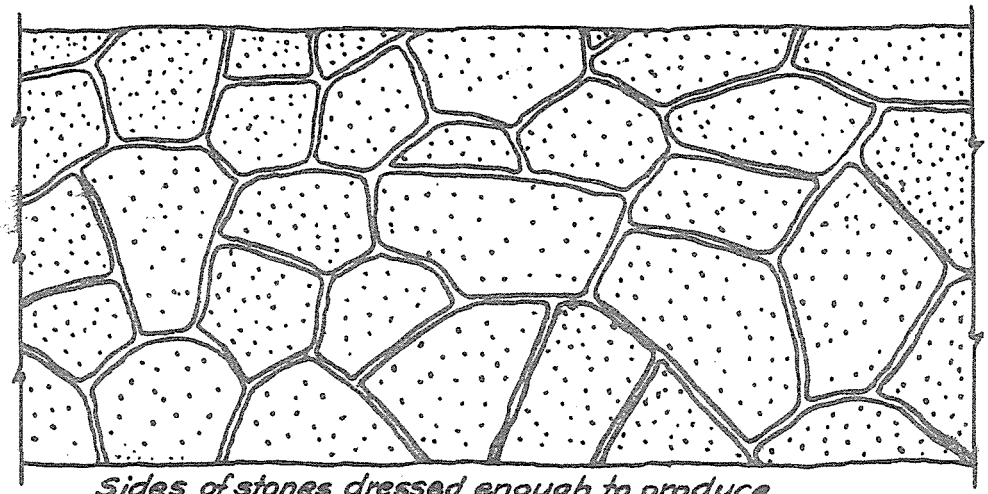
C. Sample Construction.

It is usually good practice to erect a number of sample stone walls somewhere on the site for advance inspection, criticism, and correction before the actual work is started. This procedure is comparatively inexpensive and is found very satisfactory for determining the quality of stone, the type of jointing, the pointing, and the color of the mortar to be used.

D. Laying of Stone.

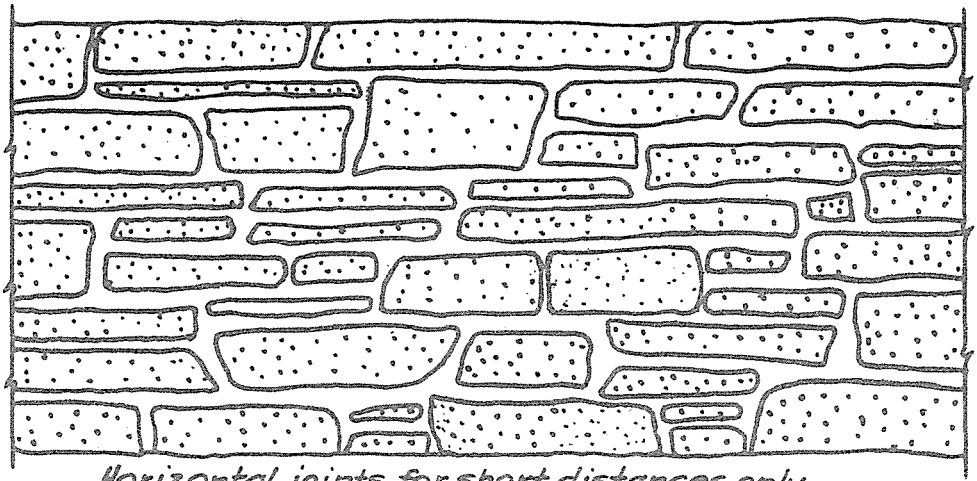
Stone should be laid on its splitting surface or bed joint to prevent the entrance of frost into the stratification-plane. Porous stone should not be used, because of the possibility of leakage of water through finished walls. Stone should be laid with the back of the bed joint higher than its front, as a further preventative against leakage. All stone should be carefully cleaned and thoroughly wetted before being placed in position. The method of placing stones is dependent upon the type of masonry being constructed.

Footing stones should be placed flat on solid ground below the normal frost line. Joints in the walls should be broken so that vertical joints in one course are not directly above those in the course below it. Long, continuous, horizontal joints are ordinarily avoided in rubble masonry construction. Joints must be carefully filled with mortar. If joints tend to become too wide, small filler stones or spalls should be used to help fill up the space between the larger stones. Rubble masonry walls should be at least 18 inches thick for the average two-story structure, and of greater thicknesses for higher structures. If the facing stones vary considerably in size and color, the larger and darker stones should be placed at the bottom. The size of stones and shades of color should decrease gradually to the top of the wall.



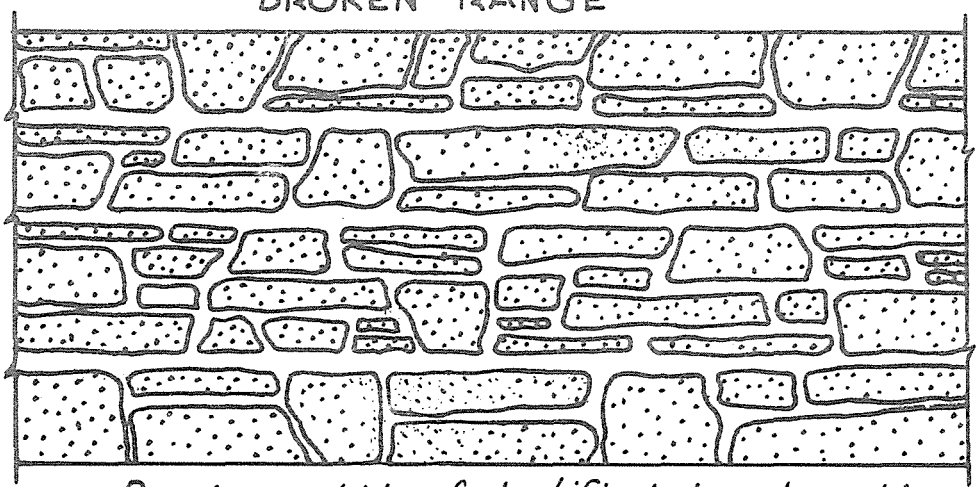
Sides of stones dressed enough to produce irregular jointing of uniform width.

POLYGONAL



Horizontal joints for short distances only approximately 8 to 10 feet.

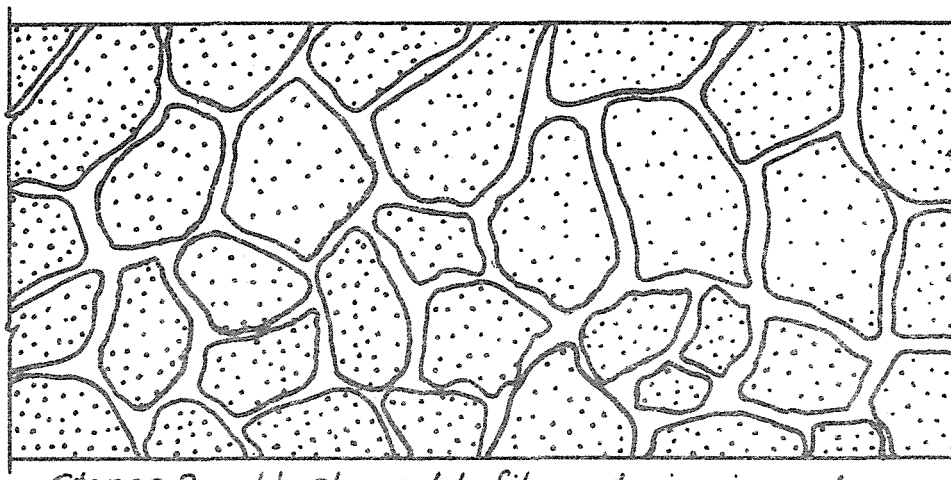
BROKEN RANGE



Random rubble of stratified stone brought to level beds at varying vertical intervals.

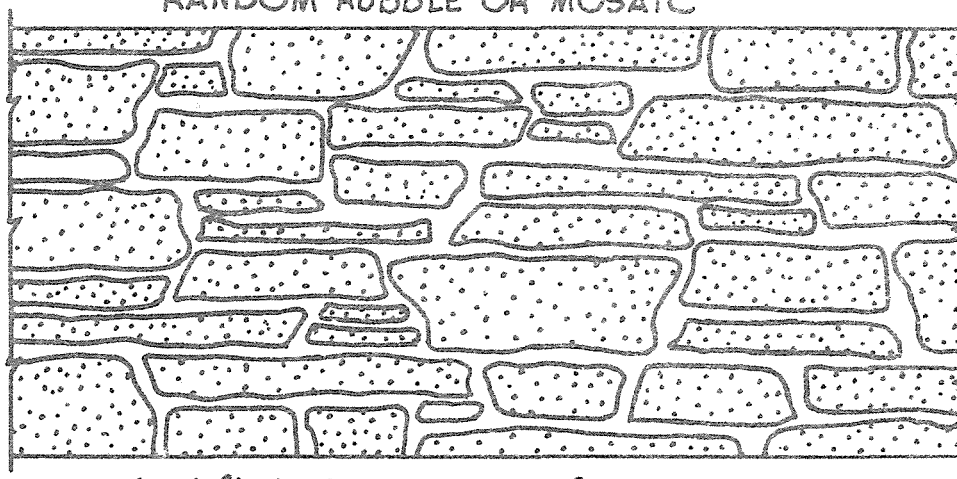
RANDOM COURSED

RUBBLE MASONRY

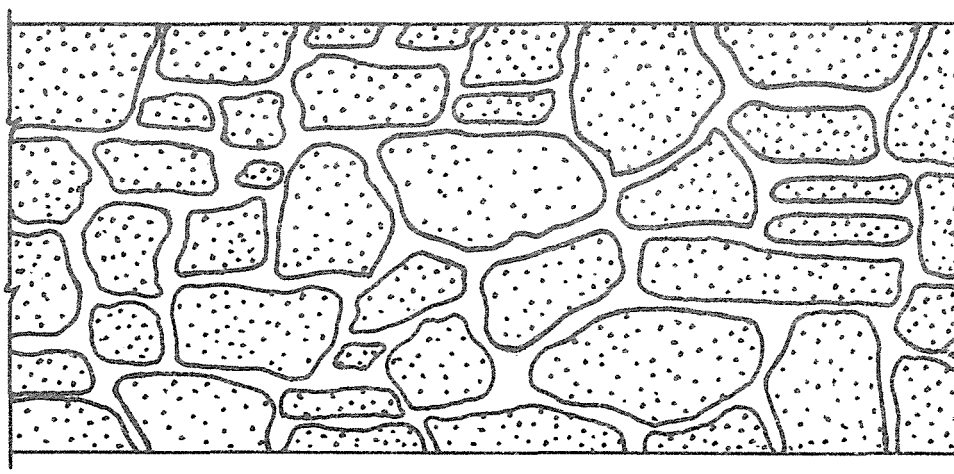


Stones Roughly shaped to fit, producing irregular joints of slightly varying widths.

RANDOM RUBBLE OR MOSAIC

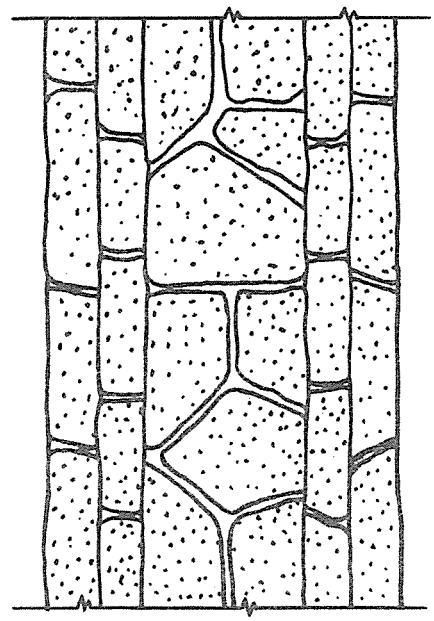


Stratified Stones having fairly level beds, as the result of natural cleavage.

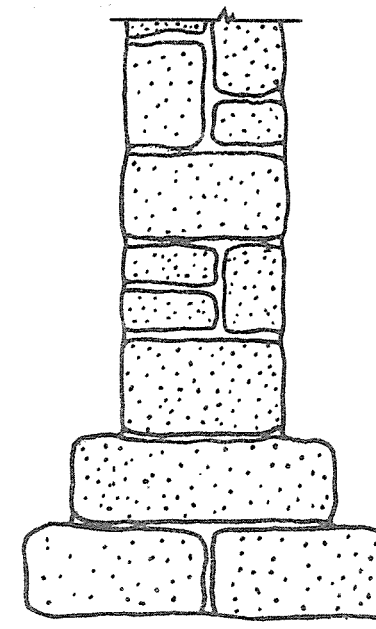


Undressed Stones producing irregular joints of varying widths.

RUBBLE MASONRY



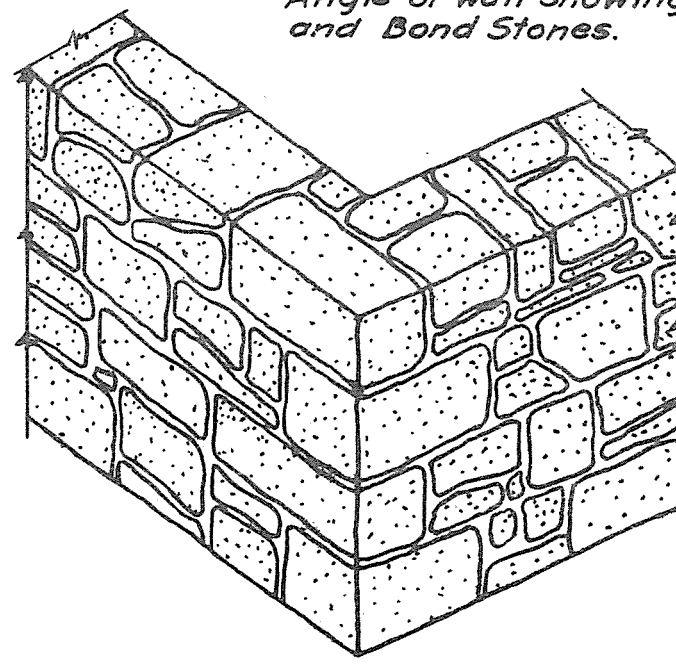
PLAN



ELEVATION

FOOTINGS

Angle of wall showing quoins and Bond Stones.



RUBBLE MASONRY

E. Batter of Walls.

Battered walls possess greater strength and a better appearance than vertical walls. They are less abrupt and rigid and conform to good engineering practice. Batters need not be excessive, but should be uniform for the entire height of the wall. Batters are especially necessary in stone wall construction in connection with bridges and dams.

F. Bonding.

Bonding is next in importance to the quality of stone and mortar used. Bonding stones should be long enough to extend through the wall or well into it. They should be placed not more than four or five feet apart and should be staggered so that the bonding stones will not be located one above the other. The corners of stone walls should be reinforced with large size overlapping header and stretcher stones, which are sometimes called quoins. The proper method of corner construction and of bonding is shown in the illustration on page

G. Jointing.

Joints in masonry walls vary with design requirements, the character of the stone, and the manner in which it is laid. Formal, dressed, tooled, or surfaced stone work, calls for uniform joints, not more than 1/2-inch in width. The width of joints in rubble masonry is not uniform, but may vary considerably throughout the face of the wall. It is the usual practice to make the vertical joints narrower than the horizontal joints.

When it is necessary to make diagonal joints because of the shape of the stones, care should be exercised to have adjacent joints running in opposite directions. In this way one joint acts as a foil to balance the other and will hold the wall more firmly in place. Continuous vertical and diagonal jointing should be avoided. Plans for walls should include notes on the types of joints to be used.

H. Pointing.

Pointing consists of filling the face joints with rich mortar after they have been carefully raked out to a depth of about 3/4 inch. This work should be of secondary importance and should never be more pronounced or conspicuous than the stone work itself. Raised joints are not desirable in rubble masonry construction. Flush or slightly depressed joints are preferred and add much to the appearance of a wall.

I. Mortar.

Considerable care should be exercised in selecting the proper color of mortar to be used for pointing. A plain gray cement mortar is usually the most satisfactory. It is sometimes desirable to use

a pure white, black, bluish black, or some shade of red mortar to harmonize with the stones used in the wall. If colors are necessary, they should be mixed by someone familiar with their use.

All stone work should be laid in a plain cement mortar, although it is often desirable to add a small quantity of hydrated lime to make the mix easier to handle. If this is done, the proportions of materials should be, by volume, as follows:

One-quarter part hydrated lime
One part Portland Cement
Three and one-half parts clean, sharp sand

Under ordinary conditions the following combinations of materials, by volume, will apply for the various mortars:

Cement Mortar - One part Portland cement
Three parts clean, sharp sand

Lime Mortar - One part hydrated lime
Three parts clean, sharp sand

Pointing Mortar - One part Portland Cement
One part fine sand

Mortar should be of a heavy batter consistency. The water used should be clean; the average amount required for mixing one sack of Portland Cement will be about 6¼ gallons. Mortar, like concrete, may be mixed by hand, or by machine. The method of mixing will be determined by the size of the job. Mortar must not be retempered and used after it has once begun to set.

163. Brick Masonry.

A. Strength of Masonry.

It is impossible to determine actual values for the strength of brick work with the exactness that is possible for wood and steel members. This is largely because of the great differences in strength of the mortars and of the bricks themselves. Recommendations as to the minimum thickness of walls for various heights of buildings are shown in the illustration on page 256.

The table on the following page will serve as a guide in determining the ultimate strength of brick work made of various kinds of brick set in mortar, the composition of which varies from neat cement to one part cement and seven parts sand. The values given are ultimate strengths and must be used in connection with suitable factors of safet

Brick walls laid with cement mortar are much stronger than those laid in lime mortar. Much stronger construction may be expected if the bricks are well wetted before being placed. This operation is an aid in preventing the bricks from drawing the moisture from the mortar and thus making a weaker joint.

Material	Composition of mortar parts	Weight per cu. ft. lbs.	Compressive strength lbs. per sq. in.
Wire-cut brick	1 cement, 5 sand	136	3,000
Dry-pressed brick	1 cement, 5 sand	137	3,400
Dry-pressed brick	1 cement, 1 lime, 3 sand	133	2,300
Recompressed brick	1 cement, 5 sand	124	1,700
Light-hard, sand-struck brick	1 cement, 5 sand	117	1,900
Light-hard, sand-struck brick	1 cement, 7 sand	109	853
Hard, sand-struck brick	1 cement, 1 sand	119	2,100
Hard, sand-struck brick	1 cement, 1 lime, 3 sand	113	1,500
Hard, sand-struck brick	1 cement, 5 sand	108	1,200
Sand-lime brick	1 cement, 3 sand	112	1,100
Sand-lime brick	1 lime, 3 sand	108	450
Sand-lime brick	neat cement	113	1,400
Terra-cotta work		112	2,000

B. Bonding.

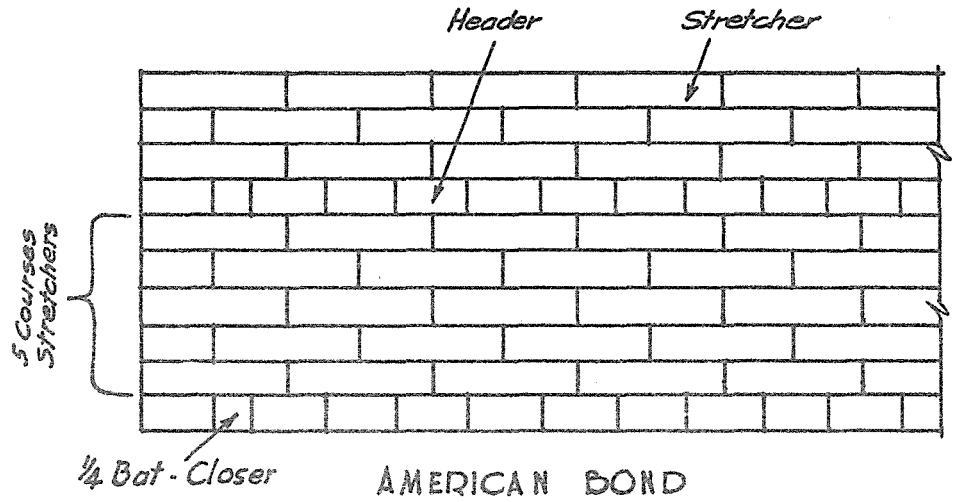
The bonding of brick work means that in the process of laying bricks across one another, one brick will rest on parts of two or three below it. When brick walls are properly bonded it will be practically impossible for them to fail by simply parting at the joints, unless the bricks are broken. Bricks are designated by different terms, according to their position in the wall. When a brick is placed lengthwise along the face of the wall, it is called a stretcher, and when it is placed with only one end exposed to view, it is called a header.

The three methods of bonding most commonly used in the United States are the American bond, the Flemish bond and the English bond. Each will be briefly described.

(a) American Bond.

The American bond is often called common bond, garden bond, or running bond. It consists of laying from four to seven courses of bricks as stretchers and then bonding with a row of headers. The number of rows of stretchers must be kept uniform throughout the construction of any wall. In the row of headers, the longitudinal lap is made solid by the use of a closer, which is simply a brick which has been split lengthwise so that it will not be more than half a brick wide. American bond is the least costly to build.

An example of this type of bonding with five courses of stretchers between the headers, is shown below.

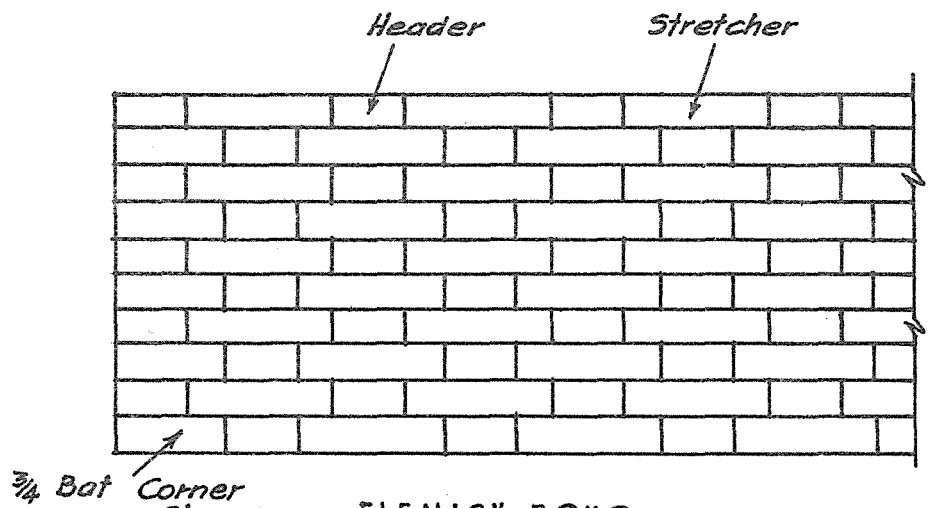


AMERICAN BOND

(b) Flemish bond.

The Flemish bond is usually used where an artistic wall surface is desired. Each course is composed of a header and a stretcher laid alternately. In order that the joints may be broken properly, every other course is started with a three-quarter length brick.

An example of this type of bonding is shown below.

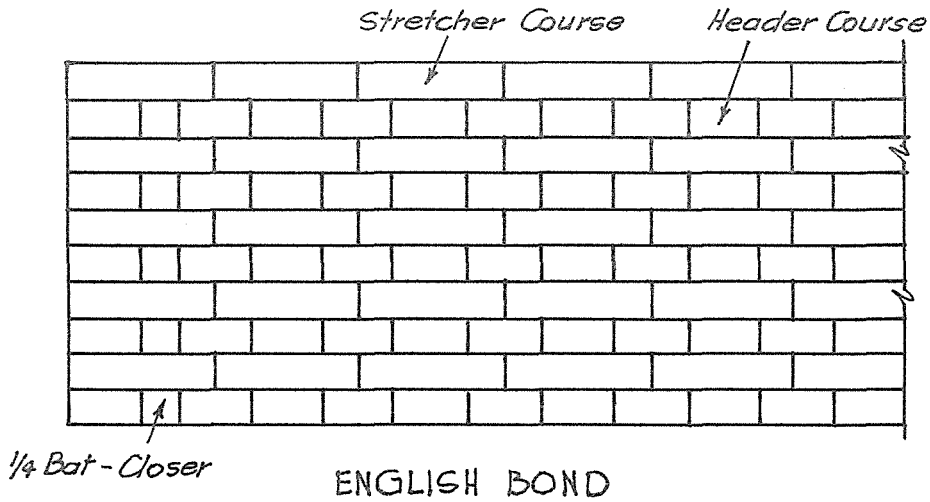


FLEMISH BOND

(c) English bond.

English bond is, in many ways, similar to American bond, except that the stretcher courses and header courses are laid alternately. As in the American bond, the longitudinal lap in the header course is secured by closers.

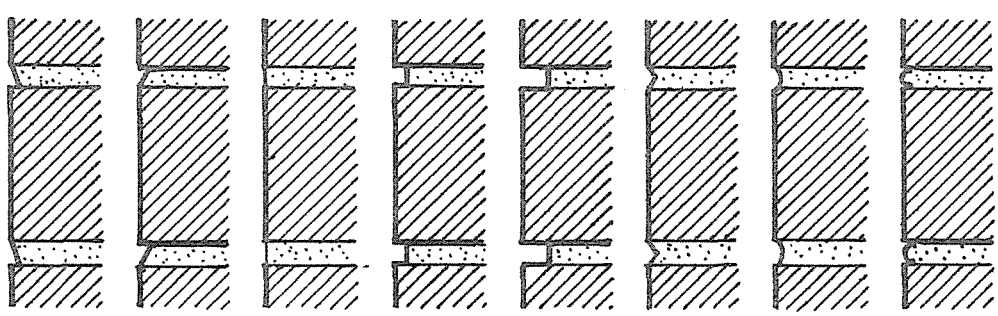
An example of this type of bonding is shown below.



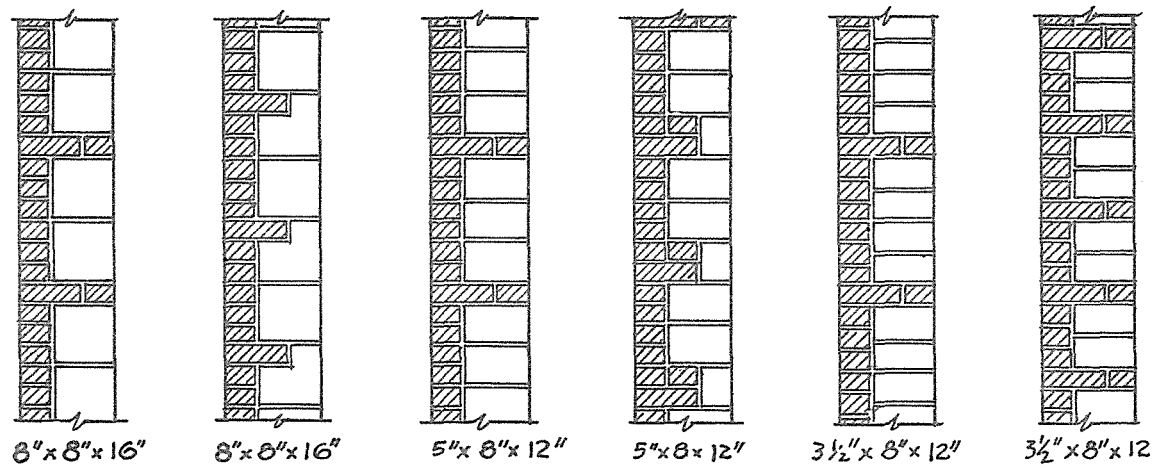
ENGLISH BOND

C. Joints.

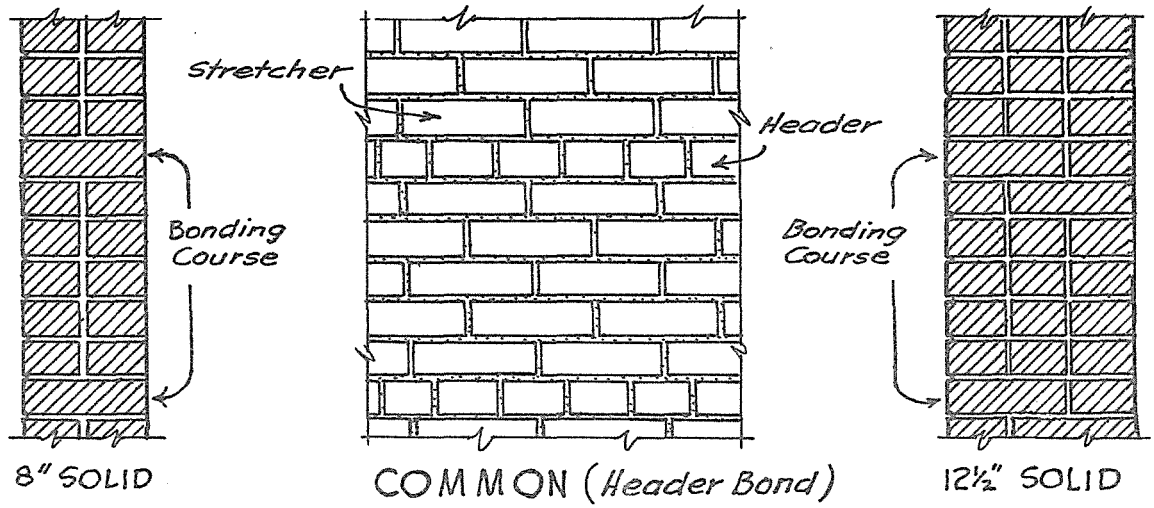
Joints in brick walls serve to hold the wall together to make it more rigid. The horizontal joints provide an even supporting bed for the bricks above it, while the vertical joints close the spaces between the bricks and keep out water. Several joint types are in common use, the most popular types being illustrated below.



The joints between the bricks should be of an even thickness and thick enough so that the individual bricks can be plainly seen. If lime mortar is used, the maximum thickness of joints should be from 1/4" to 3/8", but if lime cement mortar is used the thickness may be increased to 1/2" and still provide sufficient strength for holding the wall together.

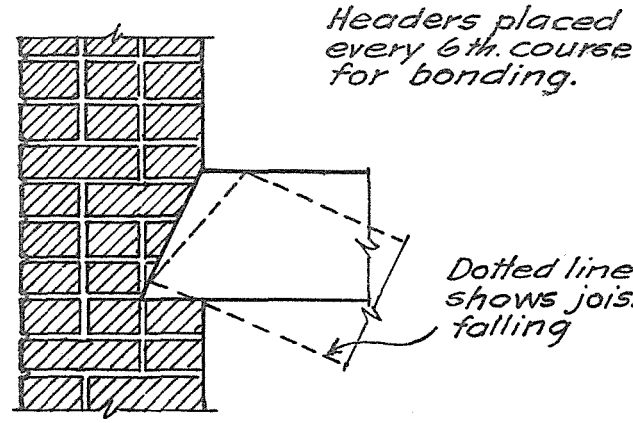


BONDING FACE BRICK

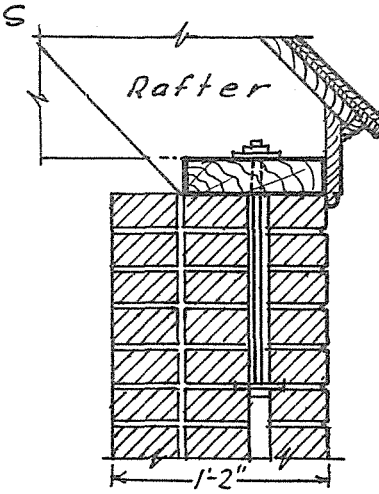


SOLID BRICK WALLS

Headers placed every 6th. course for bonding.



JOIST ANCHOR



RAFTER PLATE ANCHOR

BRICK WALLS

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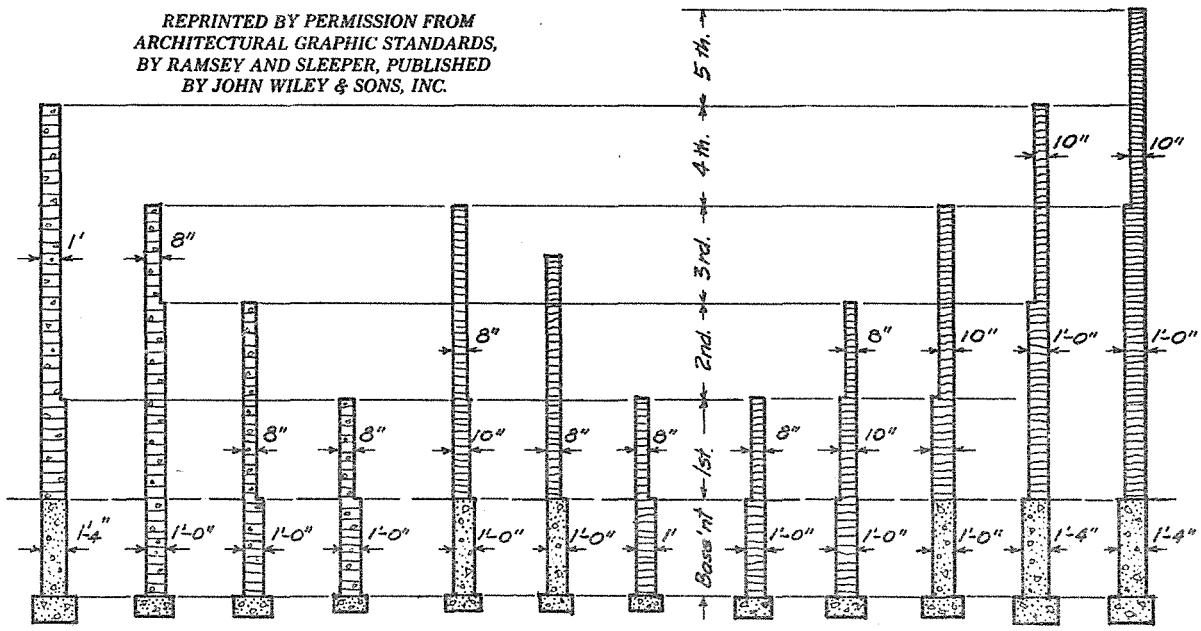
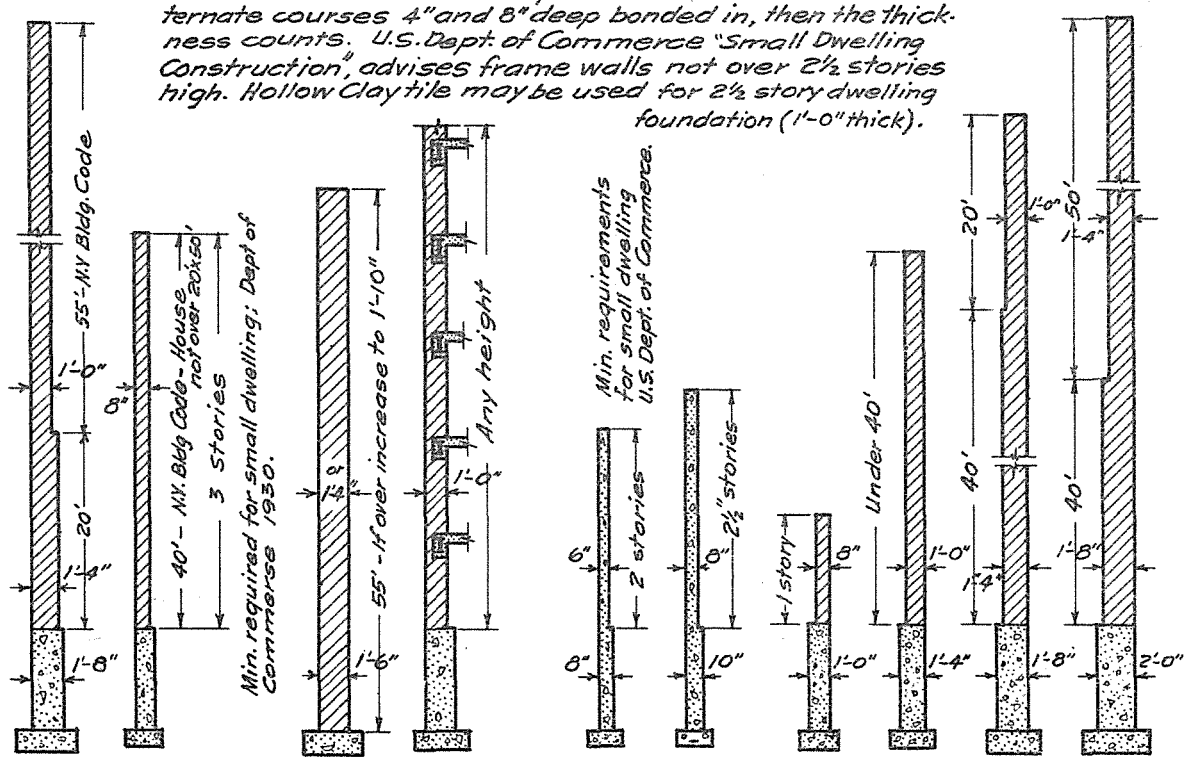


4" Stone veneer does not count as a part of walls. it is additional to thickness required: if wall is built with alternate courses 4" and 8" deep bonded in, then the thickness counts. U.S. Dept of Commerce "Small Dwelling Construction", advises frame walls not over 2½ stories high. Hollow Clay tile may be used for 2½ story dwelling foundation (1'-0" thick).



MINIMUM MASONRY WALLS

D. Mortars for Brick Work.

Bricks were formerly laid in a pure lime mortar. Later, natural cement was mixed with the lime to provide more strength. Still later, Portland Cement was added to the lime after it was found that it could be manufactured cheap enough for its economical use. At the present time, all bricks are laid in Portland Cement mortar or Portland Cement lime mortar.

The sand used for making mortar should be much finer than that used in making concrete, because of the limitations of thickness of joints.

(a) Portland-Cement Mortar.

Pure Portland Cement and sand mortar is not plastic and is hard to handle satisfactorily. It quickly loses its moisture by evaporation and by absorption by the bricks. For this reason a small amount of hydrated lime or lime putty is added to the mortar. The lime tends to retain the moisture and prolong the workability of the mortar. The usual practice is to add about 10% of lime to 90% of Portland Cement by weight After this is done, the combination is then mixed in the proportion of one part of cement-lime to three parts of sand by volume. This mixture has a compressive strength of approximately 325 lbs. per sq. in. after it has hardened.

(b) Cement-Lime Mortar.

As stated above, the addition of lime makes the resulting mortar more workable. Cement-lime mortar is similar to the Portland-cement mortar just described, except that the cement and lime are mixed in equal proportions by volume. A mortar consisting of one part Portland Cement, one part lime, and four parts sand, by volume, will have a compressive strength of 200 lbs. per sq. in., after it has hardened. A mixture consisting of one part Portland Cement, one part lime, and six parts sand by volume, will have a compressive strength of 125 lbs. per sq. in. after it has hardened.

(c) Lime Mortar.

Pure lime sand mortar is seldom used at the present time. It has very little compressive strength. A mixture of one part lime to three parts sand provides a compressive strength of only 40 lbs. per sq. in. after it has hardened.

E. Materials Required for Brick Work.

The table on the following page indicates the estimated amount of materials necessary to construct 1,000 sq. ft. of brick wall, using 1/2 inch joints.

Kind of Wall	Thickness of wall, inches	Number of Bricks	Cubic feet of mortar
American Bond, four stretchers between headers.			
Basement walls, solid	8	12,706	195
	12	19,252	314
	16	25,797	433
Walls Above Grade, Solid	4	6,161	76
	8	12,321	195
	12	18,482	314
	16	24,642	433

It has been estimated that the following quantities of materials will be necessary for making 1,000 cubic feet of mortar:

Kind	Proportion	Cement Sacks	Lime Sacks	Sand cu. yds.
Lime	1:2½		350	37
Lime	1:3		292	37
Cement-Lime	1:1:6	130	146	37
Cement	1:2	442	92	34
Cement	1:3	331	69	39
Cement	1:4	264	55	41

F. Laying Brick.

Brick walls are usually built up in layers of approximately 4 feet for the convenience of the bricklayer. Either inside or outside scaffolds may be used, but outside scaffolds are generally more desirable because the face brick may then be laid without any overhand work. Wide scaffolds are preferable for brick work, because materials may be better distributed.

Inside scaffolds are very convenient for handling the materials for brick work. The materials are carried up in hods by brick mason helpers if the buildings are not more than two stories high. Temporary elevators are usually used for higher structures.

Bricklayers usually stand about 6 feet apart when the job is large and the work must be done quickly. Each man is furnished with a mortar board or tub. At points where the wall is broken by an opening, one man should lay the brick on each side of the opening. Helpers should move so as to speedily furnish the masons with all materials for the work.

The first course of a brick wall should be laid dry to serve as a working plan to show the arrangement of the bricks and to provide for

proper spacing so that closers will not be required between the work of any two men. After the spacing has been arranged, the bricks are then laid in mortar, and the work proceeds according to the plans. The first course is usually laid as a header course.

The most experienced masons keep the leads plumb and several courses higher than the main portion of the wall. The bricklayers usually set the stone and concrete sills. They should be bedded in mortar only at the ends. The space between the brick and the underside of the sill is left unfilled to prevent the cracking of the sill due to the settling of the green masonry.

The window and door frames are set and carefully braced by the carpenters. The sills of the frames should be placed in a thin bed of mortar.

The joints between the bricks should be kept as nearly as possible to the same thickness. Deviations of thickness are easily discernible and detract from the appearance of the work. The courses of bricks should not be dipped, but should be kept level by the use of a line stretched between the leads. The line should be supported along its length so that it will mark the top edge of the course of brick being laid. As each course is laid the line is raised for the next one.

Bricks should be laid in a stiff mortar. A soft mortar has a tendency to allow the bricks to slip out of position and is also more liable to splash and smear the faces of the brick. Bricks should be kept clean while being laid, and mortar should appear only between them.

Tops of brick walls should be covered at the end of each day's work as a protection against the weather. The usual method is to place boards over the top and weight them down with bricks.

After the bricklaying has been completed, the surface of the wall should be cleaned by the use of a weak solution of muriatic acid, applied with a stiff brush. The acid should be poured into the water in the proportion of about one pint of acid to three gallons of water, or until the combined solution has sufficient strength to show effervescence when it is poured on dry mortar. If the acid solution is made too strong it may burn the brick and destroy the natural coloring or give a greasy appearance to the wall.

Practically leak-proof brick work may be obtained if the following recommendations are followed:

Select impervious face brick.
Lay the brick with joints not more than 3/8" thick.
Butter all bricks on the bottom edge.
Lay the bricks in an overflow bed of mortar so that they can be shoved edgewise into place and the vertical joint will be completely filled.
Make a weather joint as illustrated on page 254.
Use a plastic mortar.

Do not use chipped bricks.
Thoroughly wet all bricks before laying.
Carefully inspect each course as it is laid and fill all small holes and cracks between the mortar and the brick.

164. Adobe Masonry.

Structures built of adobe require concrete foundations because of the susceptibility of the adobe to disintegration when exposed to moisture. After the foundation walls have been thoroughly dried, the top surface is covered with a coat of hot asphalt. The lower floor joists are then placed in position on the concrete, and the adobe bricks are laid so as to hold the joists in position. The exposed face of the concrete foundation should be protected by building paper to prevent staining while the adobe work is being carried on.

Adobe bricks must be laid in adobe mortar using thick bed joints. All joints should be arranged so as to obtain the desired batter on the exposed faces of exterior walls.

Adobe walls must be well bonded. Bonds should be placed in each course and should run through the wall. One brick out of each 10 laid should serve as a bond.

The exterior and interior faces of the walls should be relatively true and even so that the exterior stucco and the interior plaster may be applied in coats of uniform thickness.

Wood bucks, lintels and strap anchors should be placed in their proper position as the walls are erected so that no difficulty will be encountered when the door and window frames are set.

A layer of asphalt-saturated felt should be placed over the top surface of the adobe wall to serve as a flashing under the concrete coping block.

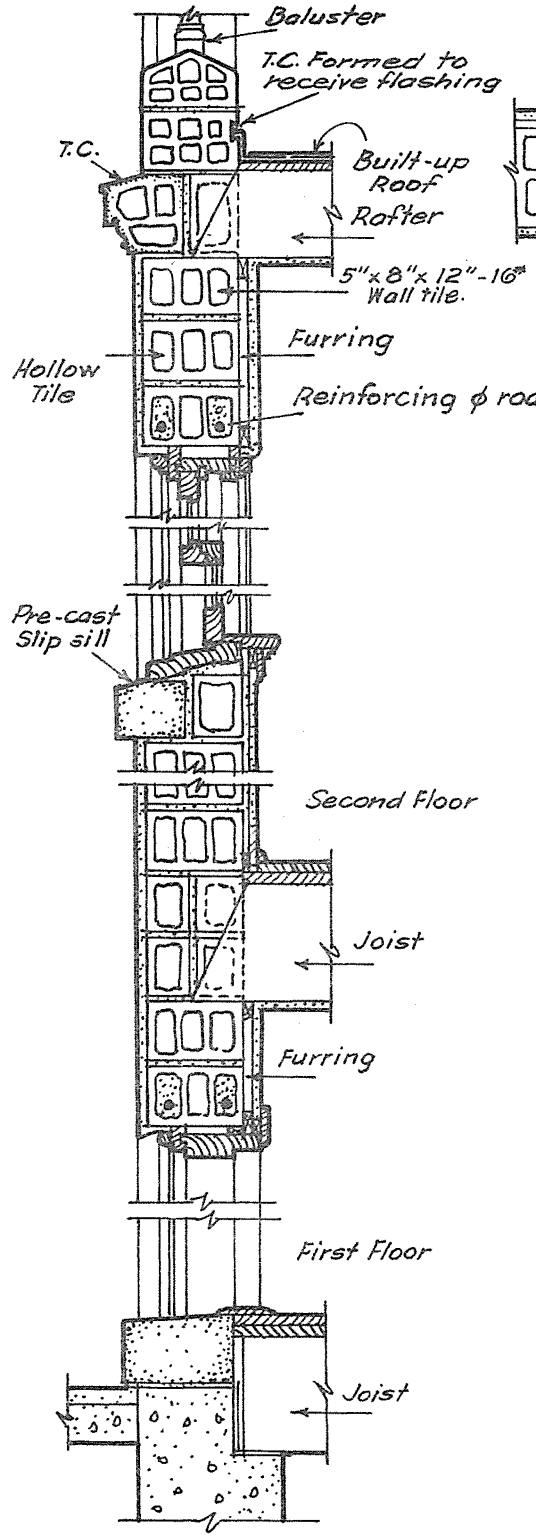
After the adobe work has been completed, the walls should be allowed to dry before the roof is placed. All adobe work must be done in a thoroughly workman-like manner, so that there will be no necessity for changes during the latter period of construction.

165. Hollow Tile Masonry.

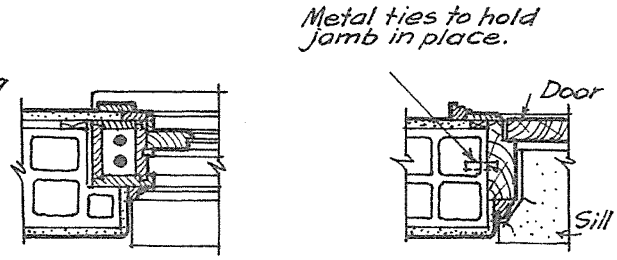
A. General Conditions.

Hollow tile shall comply with Federal Specification SS-T-341 for load-bearing walls and SS-T-351 for non-load-bearing walls.

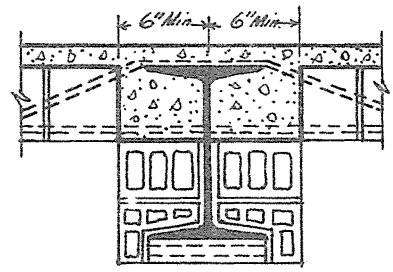
The figure on page 261 illustrates the use of hollow tile for wall construction. On the same page are shown methods of fire-proofing girders, columns and I-beams. Hollow tile is widely used for fire proof construction, but it will not stand very much vibration. Its use may be questionable in regions which are subject to earthquakes. In these regions all construction work must comply with local building codes and regulations.



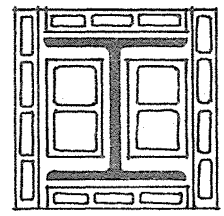
WALL CONSTRUCTION



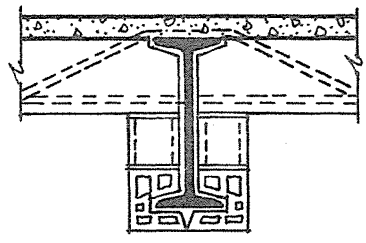
TYPICAL WINDOW AND DOOR JAMBS



SECTION AT GIRDER

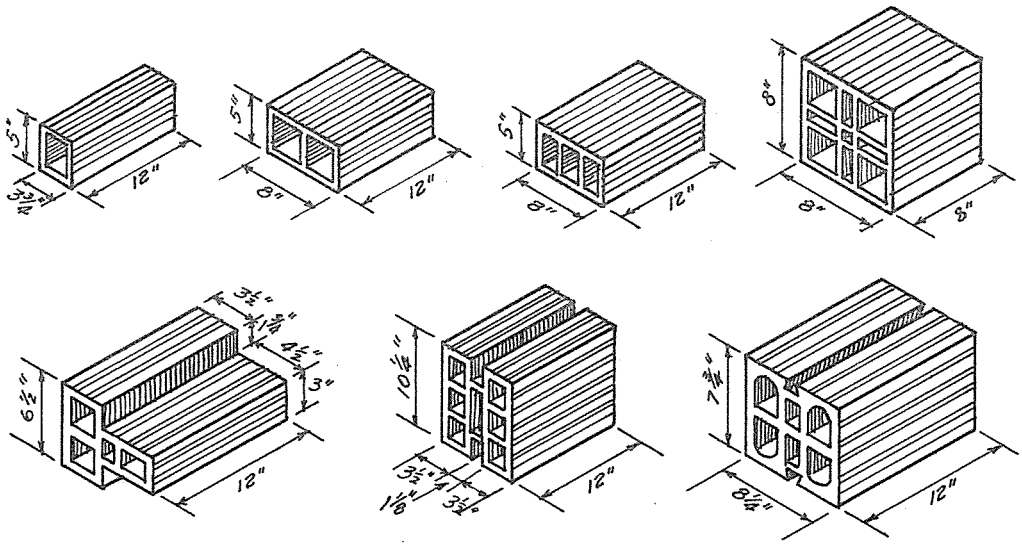


SECTION THRU COLUMN

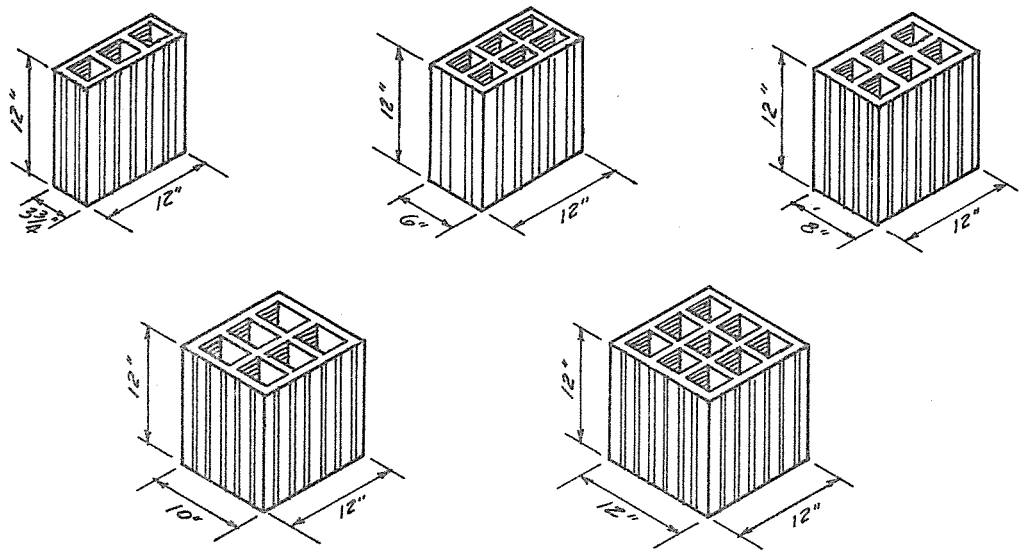


SECTION AT I-BEAM

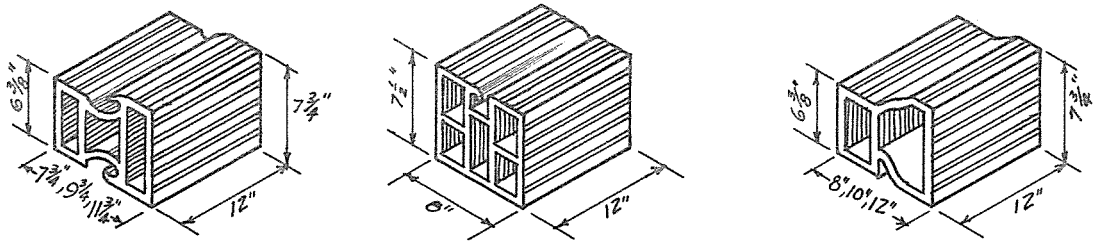
HOLLOW TILE CONSTRUCTION



TILE FOR SIDE CONSTRUCTION



TILE FOR END CONSTRUCTION



SPEED-A-BACKER

SPEED-TILE

BELL-BACKER

COURTESY OF STRUCTURAL CLAY TILE ASSOCIATION

STANDARD TILE SHAPES

Building tiles are usually set with flush joints. The mortar mix recommended for brick work may be used in tile construction.

B. Quantity of Mortar Required to Lay Tile.

The following table gives the quantity of mortar in cubic feet required to lay 100 sq. ft. of hollow tile. The thickness of tile varies from 2" to 12" and the width of mortar joints varies from 1/8" to 1". An allowance of 10% is made in the table to cover waste.

Thickness of tile in inches	Width of Mortar Joints in Inches							
	1/8"	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1"
2	3/8	3/4	1-1/6	1-1/2	1-7/8	2-1/4	2-2/3	3
3	3/5	1-1/6	1-3/4	2-1/4	2-7/8	3-1/2	4	4-3/5
4	3/4	1-1/2	2-1/4	3	3-4/5	4-3/5	5-3/8	6
5	1	1-9/10	2-7/8	3-4/5	4-3/4	5-3/4	6-2/3	7-2/3
6	1-1/6	2-3/10	3-1/2	4-3/5	5-3/4	6-7/8	8	9-1/6
7	1-3/8	2-2/3	4	5-1/3	6-2/3	8	9-3/8	10-2/3
8	1-1/2	3	4-3/5	6-1/8	7-5/8	9-1/6	10-2/3	12-1/4
9	1-3/4	3-1/2	5-1/6	6-7/8	8-3/5	10-3/10	12	13-3/4
10	1-9/10	3-4/5	5-3/4	7-5/8	9-1/2	11-1/2	13-1/3	15-1/4
11	2-1/10	4-1/5	6-3/10	8-2/5	10-1/2	12-5/8	14-3/4	16-3/4
12	2-3/10	4-3/5	6-7/8	9-1/6	11-1/2	13-3/4	16	18-3/10

C. Setting Tile.

Hollow tile should be set plumb and true to line with a regular bond. All pieces should be properly joined to other connecting work. Each piece should be set in a full bed of mortar and all joints must be filled. Face joints of interior work should be neatly struck.

Each section should be started on the structural footings. Each course should be bonded at the corners and at intersections. Vertical joints must be broken at least 3". Tile work which terminates against beam soffits, floor slabs and ceilings should be wedged tight and the joints should be filled with mortar. Partitions and furring should extend at least 3 inches above the ceiling level of suspended ceilings.

Partitions that abut unfurred walls should be bonded to them at least once for every four feet in height. Double partitions of tile less than 4 inches thick should be bonded with a through block at least once for each 10 square feet of area. Partitions of furring which enclose pipe spaces should be built only after the pipes are in place and have been thoroughly tested.

Tile which covers steel columns should be at least 3 inches thick. The tile should be set 1/2" away from the steel. All spaces between the tile and the column must be filled solidly with mortar and tile as each course is laid.

Suitable recesses should be provided in the walls for cabinets, junction boxes, etc. Exact sizes and locations should be governed by the plans. All metal work required should be built as the tile work progresses.

Tile furring should be anchored to masonry with wire netting or U-shaped wire, spaced about 2 feet apart in horizontal joints of the tile. Isolated piers of hollow tile and tile coverings for columns should be reinforced with wire netting for the full width of the tile. The reinforcement should be laid in the horizontal joints and should be lapped at the corners.

166. Concrete Masonry.

The term "concrete masonry" is applied to block, brick and tile building units, moulded from concrete and laid by masons. The concrete is made by mixing Portland cement with water and such materials as sand, gravel, crushed stone, cinders, slag, burned shale or clay. Concrete blocks shall comply with Federal Specification SS-C-621 Type #1 for load-bearing walls and Type #2 for non-load-bearing walls.

Concrete masonry is widely used in building construction because of its many definite advantages. It is economical, light in weight, durable, fire-resistant, and strong enough to carry heavy loads. It is used for both load-bearing and non-load-bearing walls, for partitions, as a backing for all types of facing materials, for fire-proofing, for floor fillers, and for almost every building construction use where masonry can be used advantageously.

Concrete masonry which is made with light-weight aggregates has excellent sound absorption qualities. This makes it particularly suitable for buildings which are designed to eliminate noise and to provide good acoustical properties.

A. Sizes and Weights.

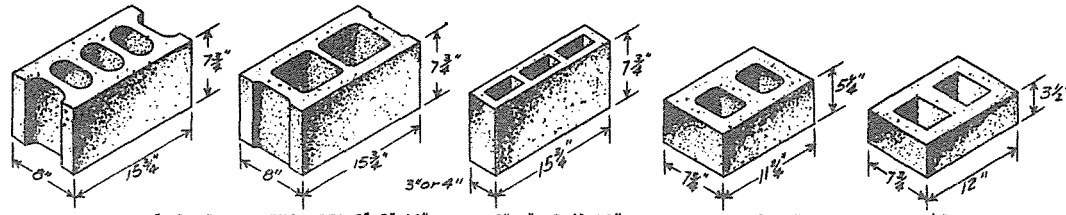
Concrete masonry units are made in several sizes and shapes. The most common size is nominally 8" x 8" x 16". When units are laid up in single thicknesses they produce a wall 8 inches thick, with the courses 8 inches high, one course being equivalent to three brick courses. Units used for partitions and veneer work are made in 3", 4" or 6" widths. Illustrations of most of the standard units are shown on page 265 .

B. Quality.

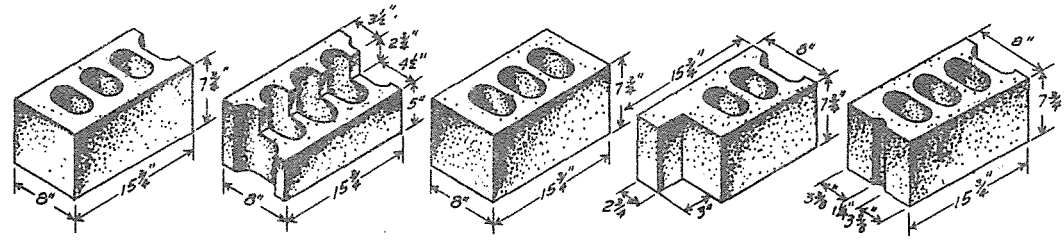
Modern methods produce concrete masonry units which easily meet all building requirements as well as specifications of the American Society for Testing Materials. Strength requirements usually range between 700 and 800 lbs. per sq. in. in compression for load-bearing units. The strength requirements are usually waived for non-load-bearing units, such as partitions. Concrete masonry units are required to remain within certain absorption limitations expressed in weight or percentage of water when they are to be used in walls exposed to the weather or to soil.

C. Wall Thickness.

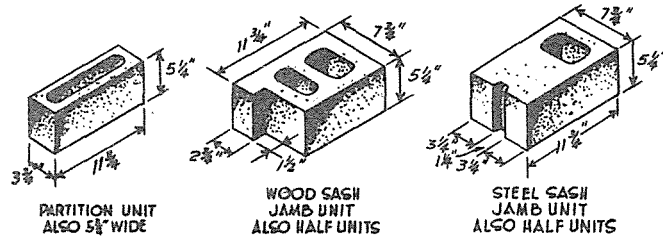
The thickness of concrete masonry walls is regulated by building codes. The usual specified minimum thickness for exterior walls



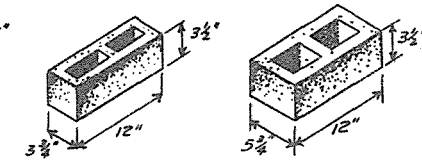
TYPES OF CONCRETE WALL UNITS - STRETCHERS



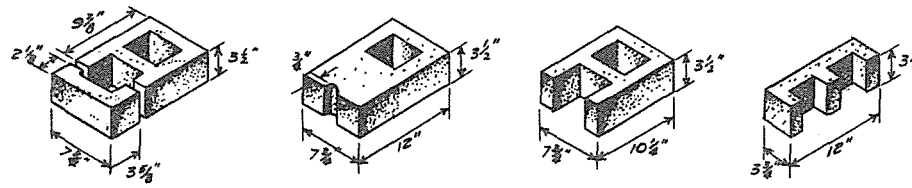
STANDARD SPECIALS FOR 8" UNITS ALSO MADE IN TWO CORE TYPE
Similar specials are regularly furnished for 10"+12" Units.



SPECIALS FOR 5"x 8"x 12" UNITS



SPECIALS FOR 3½"x 8"x 12" UNITS



COURTESY OF PORTLAND CEMENT ASSOCIATION

CONCRETE BLOCK SHAPES

and for load-bearing interior walls is 8 inches. Partition and curtain walls may be 3, 4, or 6 inches thick. The thickness of bearing walls is properly governed by the limitations of loading. The allowable working loads are commonly 70 lbs. per sq. in. of gross wall area, when the units are laid in 1:1:6 Portland cement-lime mortar, and 80 lbs. per sq. in. of gross wall area when they are laid in 1:3 Portland cement mortar.

D. Mortar.

A mortar consisting of one part of Portland cement, one part of lime, and six parts of clean sand, all measured by volume, is recommended for ordinary concrete masonry work. A mortar consisting of one part of Portland cement and three parts of sand, measured by volume, with an addition of 10 lbs. of lime for each sack of cement used, is recommended for maximum strength. Mortar of this consistency should be used for load-bearing walls in areas subjected to earthquakes, hurricanes or other severe stresses.

E. Construction Details.

Details of construction will not be set up in this handbook, but may be obtained from the pamphlet entitled "Facts About Concrete Masonry", published by the National Concrete Masonry Association.

F. Specifications.

The following specifications are quoted from "Facts About Concrete Masonry". They are from Section 22 of the Underwriters' Laboratory standard specifications for hollow concrete blocks.

(a) General.

This standard covers hollow concrete blocks which have been shown by fire tests to be eligible for a C-3 classification under standard fire exposure conditions as specified in the American Standard Fire Test Specifications.

This standard is based upon records of tests and field experience and is subject to such revision as further experience and investigations may show to be necessary or desirable.

Devices or products which comply with the standard will not necessarily be acceptable if they have other features which, when examined and tested, are found to impair the results contemplated by this standard.

A device or product having materials or forms of construction differing from those detailed in this standard may be examined and tested according to the intent of the standard and if found to be substantially equivalent may be given recognition.

(b) Strength.

Hollow concrete blocks shall have an average strength in com-

pression of 700 lbs. per square inch of gross cross-sectional area as laid in the wall, when tested not more than 28 days after manufacture. Individual units shall have a minimum compressive strength of 600 lbs. per square inch gross cross-sectional area when tested not more than 28 days after manufacture.

Solid concrete blocks shall have a minimum strength in compression of 1,000 lbs. per square inch as laid in the wall when tested not more than 28 days after manufacture.

(c) Dimensions.

The height of hollow and solid blocks shall be not more than 8 inches (nominal). The width, (or thickness) of hollow and solid blocks shall be not less than 8 inches, (nominal) as laid in the wall.

The length of hollow and solid blocks shall be not less than 12 inches nor more than 16 inches (nominal).

Face shells (side walls) of hollow blocks, except those made with fine and coarse Haydite aggregate, shall average not less than 1-3/4" in thickness and shall be not less than 1-1/2" thick at their thinnest point.

Face shells (side walls) of hollow blocks made with fine and coarse Haydite aggregate of the type hereinafter specified shall average not less than 1-1/2" in thickness and shall be not less than 1-3/8" thick at their thinnest point.

Internal and end webs of hollow blocks shall average not less than 1-1/4" in thickness and shall be not less than 1-1/8" thick at their thinnest point.

End webs of units except those made with fine and coarse Haydite aggregate, which are adaptable for use in both 8 inch and 12 inch walls, (laid all header courses in 12 inch walls), shall have an average thickness of 1-3/4" and shall be not less than 1-1/2" thick at their thinnest point.

The end webs of such units when made with fine and coarse Haydite aggregate of the type hereinafter specified, shall have an average thickness of 1-1/2" and shall be not less than 1-3/8" thick at their thinnest point.

(d) Design.

One-piece units with two or three rectangular or oval core holes and with plain or ornamental facing shall be considered as standard.

(e) Cement.

Standard Portland cement conforming to Federal Specification SS-C-191a, shall be used.

(f) Aggregate.

The aggregate used, both fine and coarse, including the sand, shall be secured from sources insuring uniformity in quality and kind.

Coarse aggregates other than cinders and Haydite shall not contain more than 65 percent by weight of siliceous material.

Cinders, when used as either fine or coarse aggregate or both, shall be of good quality, resulting from the combustion of bituminous coal or a mixture of bituminous and anthracite coal.

When cinders are used, the average combustible content of the mixed fine and coarse aggregate shall not exceed 35 percent by weight of the dried mixed aggregate.

Fine and coarse Haydite aggregate, when used, shall consist of crushed clinkers resulting from the burning of crushed shale or clay. The weight of the dry rodded fine aggregate shall not be less than 50 lbs. per cu. ft. or more than 70.5 lbs. per cu. ft. The weight of the dry rodded coarse aggregate shall be not less than 42 lbs. per cu. ft. or more than 63.5 lbs. per cu. ft.

Asbestos fiber, when used as an admixture, shall be added to the combined fine and coarse aggregate in a proportion not to exceed 10 lbs. per standard 94 lbs. bag of cement.

In general, acceptable results of a single analysis shall suffice to indicate compliance of a specific lot of material with this specification. In case of question as to compliance of material with the requirement, this average shall be determined by analysis of not less than three representative samples of the lot, and in no case shall an individual sample contain more than 10 percent by weight of combustible material in excess of the specified average.

(g) Proportion.

The cement-aggregate proportion for hollow and solid blocks shall be 1:3, 1:4, 1:5, 1:6, 1:7, or any fraction thereof not over 1:7. (by volume-dry).

At least 25 percent by volume of the mixed aggregates, including cinders and Haydite, shall be coarse aggregate, retained on a 1/4 inch screen. It is recommended that the coarse aggregate pass a 5/8 inch screen and that the maximum size of individual particles should not exceed one-half the thickness of the thinnest web or shell member of the unit in which they are used.

(h) Consistency.

The concrete used in the manufacture of hollow or solid blocks may be of a dry, damp, wet damp or wet consistency.

No change in an established practice as to the consistency of the material shall be made until strength and other tests have been made on specimens representative of the new consistency.

(i) Curing Methods.

Hollow and solid blocks may be air, water or steam cured. Water or steam curing is preferred, due to the resultant uniformity of strength and other characteristics.

All blocks shall be held in storage for a period of not less than 28 days (including curing period) unless strength and other tests have indicated compliance with the standard of blocks shipped prior to that time. In cases where blocks are shipped before 28 days, steam or water curing is considered essential.

It is recommended that blocks be held in storage for at least 10 days after manufacture.

(j) Fire Endurance Tests.

When fire endurance tests are made on blocks not clearly conforming to all of the specifications of this standard, to determine their eligibility for classification and listing, the program of the American Standard Fire Test Specifications shall be followed, except that panels may be not more than 6 x 6 ft., exposed areas. The Fire Hose Stream Test may be omitted, if, in the judgment of the testing body, the data secured therefrom are not required to confirm or supplement that secured in the fire endurance test.

167. Chimneys and Fireplaces.

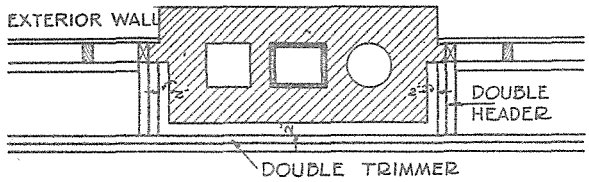
Chimneys may be made of brick or stone or a combination of the two. All chimneys must be provided with fire clay flue liners of the proper size. Metal safety flues are often used as a substitute for chimneys in temporary buildings. If they are properly constructed, they will give good safe service for some time. They require constant attention because of the possibility of burning out and causing a fire hazard.

Concrete chimneys have been used in some instances, but have never proven entirely satisfactory because of their tendency to crack. They should be reinforced both vertically and horizontally. Reinforcement increases the cost, and as a result concrete chimneys are not as economical as those made of stone or brick.

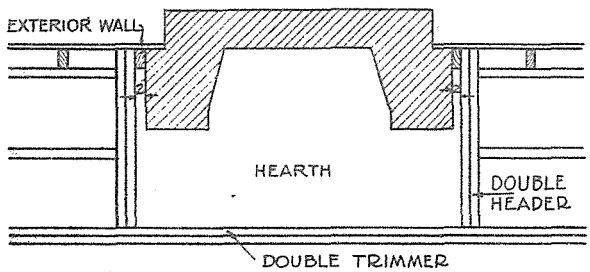
A. Specifications for Brick Chimneys.

The walls of brick chimneys shall not be less than 3-3/4" thick, exclusive of the flue lining. Bricks shall not be set on edge in chimney construction. All brick shall be laid in a full bed of mortar, and the use of "buttered joints" is specifically forbidden. Information pertaining to chimneys is illustrated on page 271.

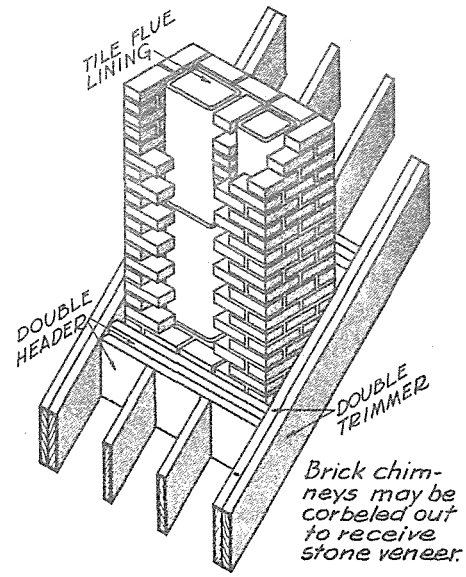
NOTE – SEE NATIONAL LUMBER MANUFACTURERS ASSOCIATION "STANDARD BUILDING ORDINANCE" FOR REGULATIONS REGARDING CHIMNEY AND FIREPLACE CONSTRUCTION.



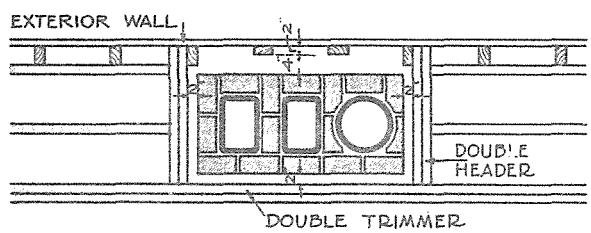
CHIMNEY ABOVE FIREPLACE



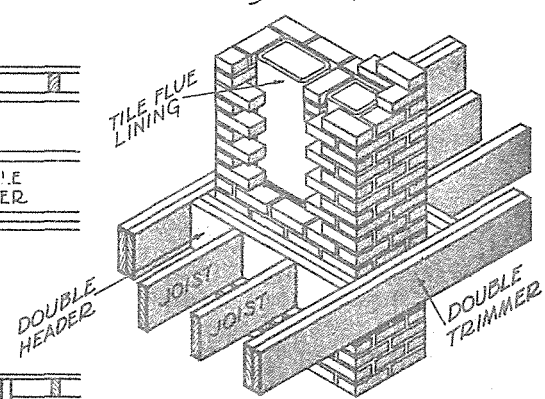
PLAN OF FIREPLACE



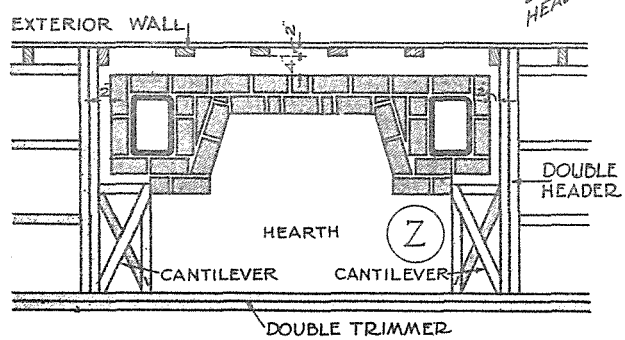
CHIMNEY AT ROOF



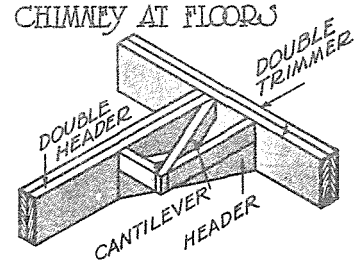
CHIMNEY ABOVE FIREPLACE



CHIMNEY AT FLOORS



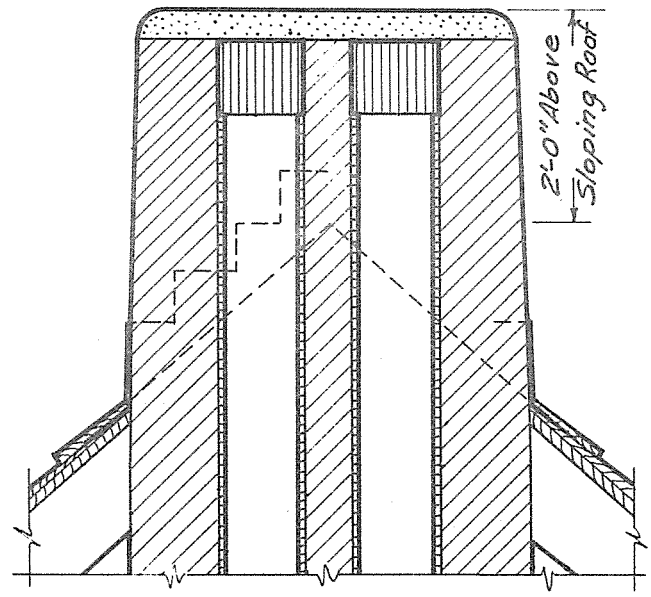
ALTERNATE PLAN OF FIREPLACE WITH ADDITIONAL FLUES SHOWN

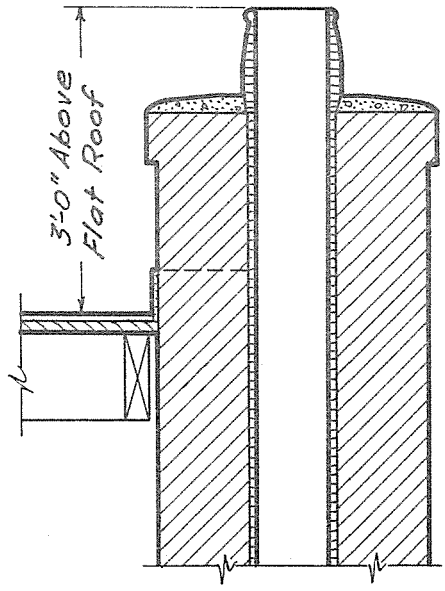


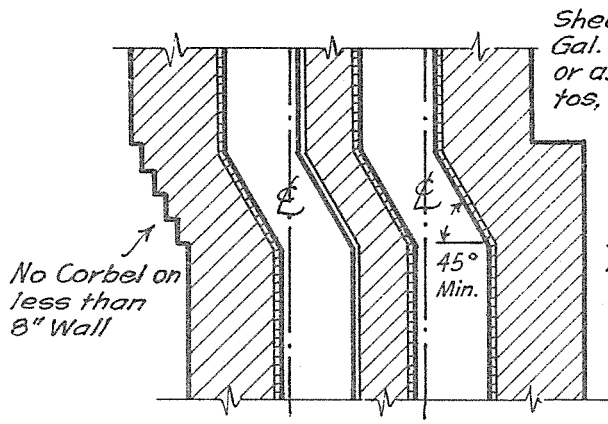
DETAIL AT Z

BY COURTESY OF
NATIONAL LUMBER MANUFACTURERS ASSOCIATION

CHIMNEY FRAMING

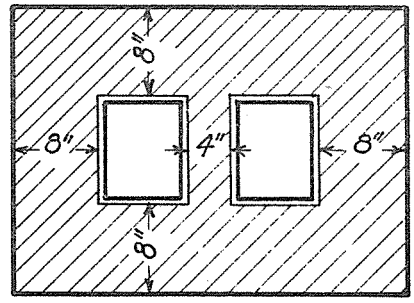




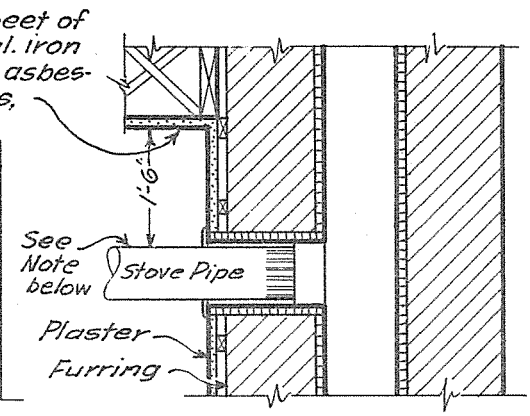


CHIMNEY OFFSET

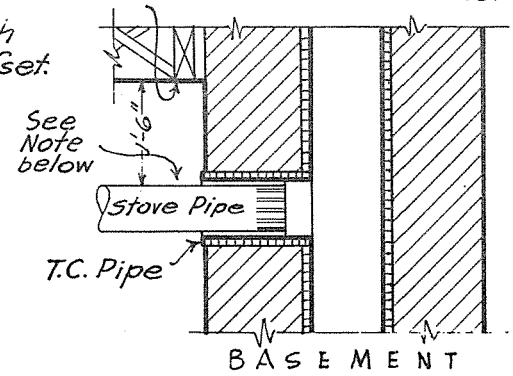
Center of Gravity must fall within width and thickness of chimney below offset.



MIN. CONSTRUCTION AROUND FLUE



Sheet of Gal. iron or asbestos.



STOVE PIPE FLUE CONNECTIONS

Note: If closer than 18" to ceiling, cover pipe with 1" thick asbestos pipe covering.

CHIMNEY CONSTRUCTION

Chimneys that have openings within their width or depth shall have tie rods located over the openings to relieve the thrust.

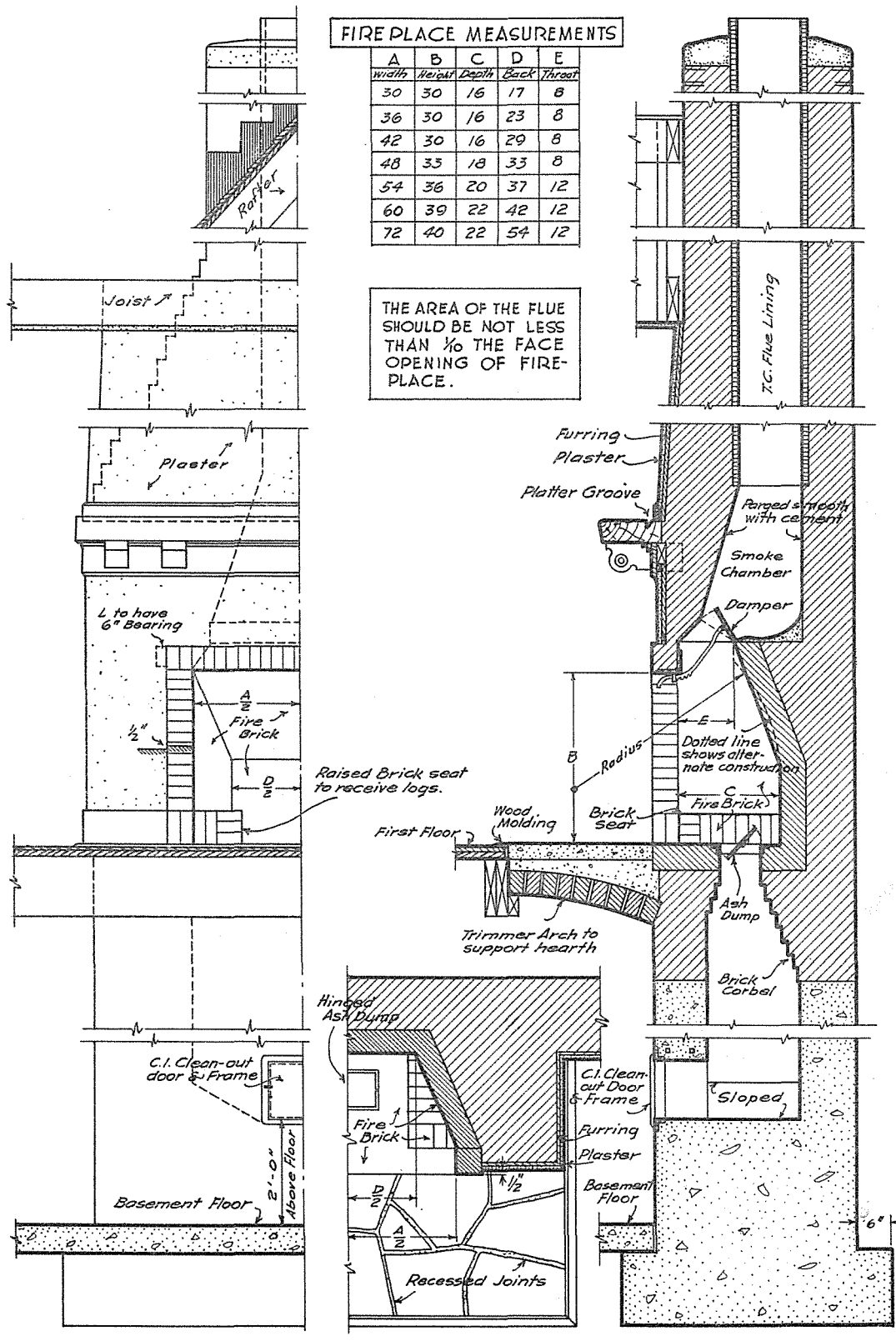
Chimneys should be centered on the footings and should be built without a lining to within 12 inches of the first smoke pipe opening. The hollow center in small chimneys up to, and 2 inches above, the beginning of a lining, may be filled with dry earth or sand. All chimneys with flue openings 8" x 12" or larger, should be provided with metal cleanout doors. These should be placed close to the ground to facilitate the removal of soot.

The total offset overhang or corbel of an independent chimney shall not exceed 3/8 of the width of the chimney in the direction of the offset. The supporting base of the chimney should be considered as the controlling factor.

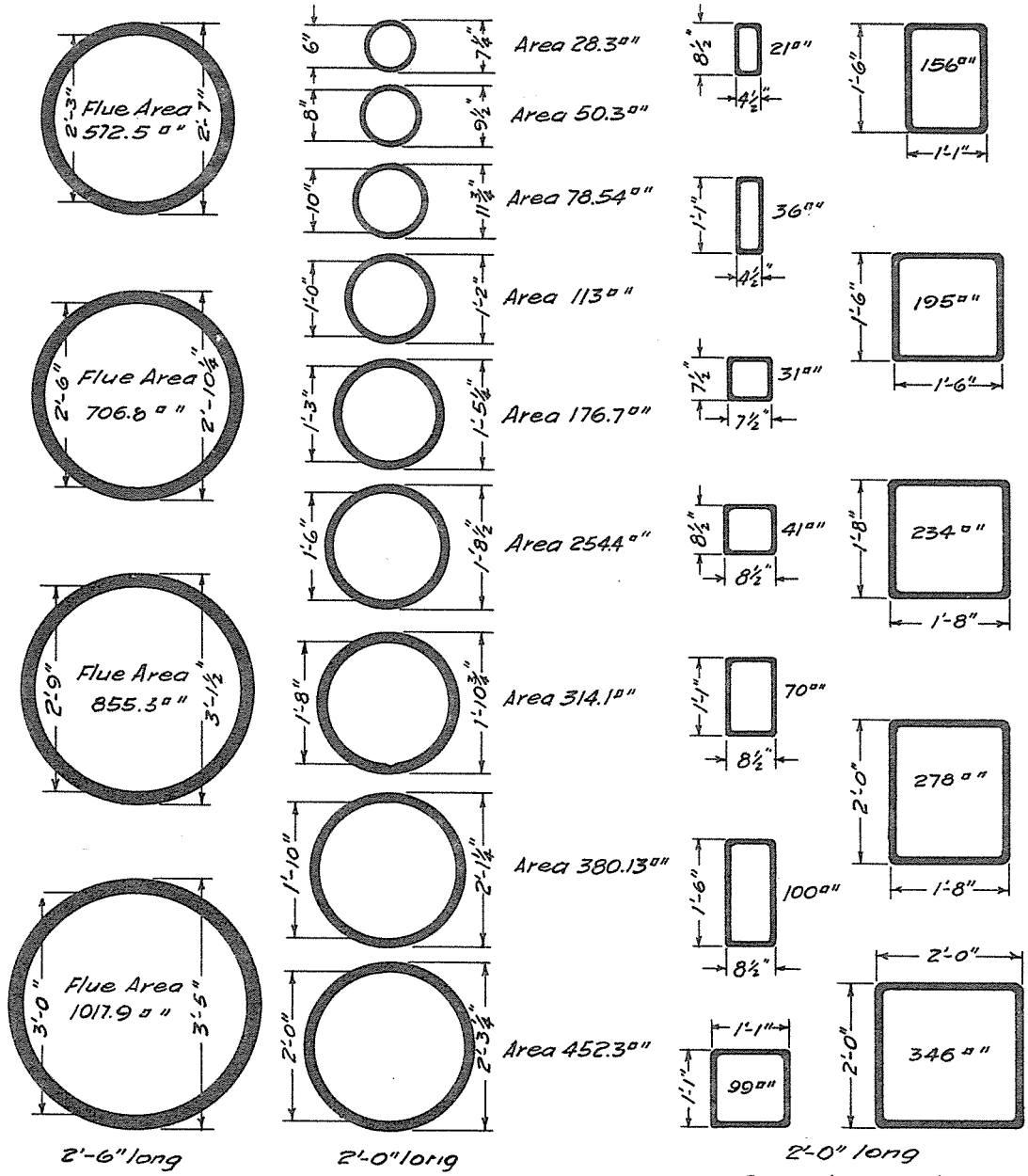
Corbel chimneys shall not be supported by hollow walls or walls built of hollow units. Solid walls which support corbel chimneys shall not be less than 12 inches thick and the corbelling shall not project more than 1 inch per course and not more than 6 inches altogether.

The following paragraphs were taken from "Standard Ordinance for Chimney Construction", as recommended by the National Board of Fire Underwriters:

> Not more than two lined flues shall be permitted in the same flue space, and the joints of any such adjoining flue linings shall be staggered at least seven inches.
>
> Flue spaces shall be separated by smoke-tight withes of masonry, not less than 3-3/4" thick, bonded into chimney walls.
>
> Flues used for heating furnaces, boilers or fireplaces shall be separated from other flues by means of withes.
>
> There shall be but one connection to a flue, irrespective of whether the flue be used for coal, coke, wood or oil.
>
> Smokepipes shall enter the chimney through a fire clay or metal thimble or flue ring of masonry. The top of smokepipe intakes shall not be less than 18 inches below sheet metal ceilings, wood lath and plaster, or exposed wood joists. Neither the intake pipe nor the thimble shall project into the flue. No woodwork shall be placed within 6 inches of the thimble.
>
> It is important that flues be constructed as nearly vertical as possible since each offset retards draft and offers a lodging place for the accumulation of soot. When the direction of the flue must change, it should preferably not depart more than 30° from the vertical and in no case more than 45°.



FIREPLACE DETAILS



Round Flue lined - Entire Area is effective.

Square Flue. Area of circle is effective.

Rectangular Flue. Entire area effective except corners

EFFECTIVE AREAS OF CHIMNEY FLUES

Fireplace Flue sizes: - 1/10 Area of Fireplace opening recommended. Absolute minimum size: - 1/12 Area of Fireplace opening. Flues are never less than 70 sq. in. effective area. Flues for stoves and ranges and Room heaters: - 30 sq. in min. using rectangular flue, or 6" dia. (inside) using round flue. Flues for Gas Furnaces, Boilers and Automatic Water Heaters to be same size as for coal. Vents for other Gas fired equipment may be smaller, but should never be less than 10 square inches.

FLUES

B. Foundations.

Building plans should indicate the proper foundations or bases for chimneys. Safe construction practice requires that chimneys rest on foundations placed on the ground or on basement walls which have been properly protected to support the additional weight.

Chimney foundations should be of concrete or solid masonry, properly proportioned to carry the weight without settlement or cracking. Footings for exterior chimneys should start below the frost line.

C. Lining.

All chimneys must be well lined with standard flue tile. The lining should start from a point 12 inches below the bottom of the first smoke pipe opening and should extend to the top of the chimney. If the chimney is not provided with a cap, the lining should project 4 inches above the top.

Standard flue tile is available everywhere. It is highly fire-resistant and if it is properly placed there should be no danger of fires starting from openings in the chimney. Sections of tile lining are made with openings to facilitate the entrance of the thimble. The openings are scored in the lining so that the thimble disc can be removed without injury to the rest of the flue.

As a support for the lining, the bricks should extend 1/2" into the inside hollow of the chimney at the bottom of the first section of tile. The chimney should be built around each tile as it is placed and all spaces between the masonry and the lining should be filled with mortar to the top of the brickwork. Special care should be used in placing the sections and in sealing the joints. Illustrations of flues and linings are shown on page 274.

D. Mortar.

Chimney mortar should be made of cement, lime and sand. The following formula conforms to most building ordinances and provides high strength mortar:

2 parts Portland cement, by volume
1/2 part dry, hydrated lime, by volume
6 parts clean sharp sand, by volume

The cement and lime should be mixed thoroughly while dry. The sand should then be added. After the component parts have been thoroughly mixed, sufficient water should be added to produce mortar of the proper consistency. Too much water should not be used. The mortar should be mixed in small batches so that it may be used within 30 minutes after mixing. The sand which is used should pass a 12 mesh screen.

E. Height above Roof.

Chimneys shall be built at least 3'0" above flat roofs, and not less than 2'0" above the ridge of gable and hip roofs, or the high point of mansard roofs. These heights are irrespective of the distance of the chimney from such obstructions to draft.

F. Thimble Construction.

Smoke pipe intakes sufficient to meet all future needs, should be provided when the chimney is built. Metal, terra cotta, or fire clay thimbles of the proper size should be securely set with mortar as the work progresses. The top of all smoke pipe openings should be at least 18" below the ceiling line.

G. Chimney Flashings.

The proper connections between the chimney and the roof should be made as described in Chapter XIX. An illustration of chimney framing is shown on page 270.

H. Maintenance.

Chimneys should be provided with a good draft and kept free from soot. The natural accumulation of soot must be kept well below the smoke pipe openings. Chimneys should be cleaned and carefully inspected at least once each year. All chipped and broken mortar should be replaced and all cracks should be filled with fresh mortar. Needed repairs should be made to the chimney cap or spark arrester, which should be kept rigid at all times.

I. Patent forms for Fireplace Construction.

Many patent fireplace forms are available. They offer many advantages in service and efficiency and are usually worth in utility the added expense they incur in construction.

J. Fire Brick Linings.

Fire bricks used for lining fire places and fire boxes, are usually 4 inches wide. They are laid in fire clay and mortar, to which 25% of Portland cement has been added. All joints between bricks must be completely filled. Thin joints are preferable and joints should not be wider than 1/4". On ordinary jobs, 300 lbs. of fire clay and 75 lbs. of Portland cement will provide a sufficient amount of mortar to lay 1,000 average size fire bricks.

CHAPTER XVII - STEEL ERECTION

168. General.

Steel is not generally used in Forest Service structures except for certain types of bridges, for lookout towers and for columns or beams in large buildings. Structural steel must conform to Federal Specifications QQ-S-711 - "Steel, Structural, for Bridges," Class A, non-copper.

The work of erecting a structural steel frame is principally a job of assembling. Each member is marked in the fabrication shop with letters and numbers for identification. The erection diagrams are simple single line drawings which show the location of each member by the position of its identification number.

169. Safety Precautions.

Forest Service safety regulations must be followed.

It is possible to erect steel members by hand, but this practice should be discouraged. Any man who works "high" is apt to have insecure footing and may drop a member when lifting it. There is nothing to stop its fall and it is apt to cause considerable damage while falling. If the members are hoisted by means of a block and tackle, there is little chance of their falling as the erector pins them into place. Should he let go of the member, it will still hang by the rope.

170. Preparing the Foundation.

The top of the concrete foundation must be carefully prepared to receive the base plate at the foot of the column. The base plate must be set level. The foundation may be built slightly above grade and then chipped and bush hammered down to the exact grade fixed for the bottom of the base plate.

Another method is to construct the foundation slightly below grade and then place a steel plate in a thin bed of grout on top of the foundation. The top surface of the plate must be set exactly to line and grade. When this method is used, a way must be provided for releasing the trapped air in the grout under the columns.

This may be accomplished by pouring the grout under a slight head and then manipulating it with a thin tool with an offset handle which may be inserted between the top of the concrete and the base of the column. The first pouring of the grout should be approximately 75% of the total volume required.

After the excess water has been given time and opportunity to drain off, additional grout should be added and manipulated to insure a complete filling so that a uniform bearing may be obtained. It may

be possible to pour the grout through one or more of the anchor bolt holes, from which it will spread to the outer edges.

171. Setting Columns.

A pole derrick or "dutchman", with a winch attached is convenient for erecting heavy steel columns. If the structure which is being erected covers an extensive area, a revolving crane or a movable derrick called a jinniwink may be used to advantage in the framework erection. A guy derrick or gin pole is usually used for high structures.

Columns are lifted by the derrick and set in place on the foundation. A sling chain, provided with a round hook and ring, should be placed around the steel column just above the center of gravity. Wire rope slings may be used, but they should be protected against cutting. Column erection is illustrated on Page 279.

While the column is being lowered into place, the connection holes should be guided into line by the insertion of a punch or the spud end of a structural wrench. The splice connection should be temporarily secured by bolts in each splice plate. One or two drift pins of the same diameter as the holes should be inserted in the holes of each column splice to hold the column rigid and prevent it from swaying until the horizontal beams and other members are connected. The drift pins are later replaced by bolts or rivets.

172. Erection of Girders or Beams.

Bridle slings made of wire rope are best for handling girders and beams. The bridle should be equipped with round hooks and be protected against cutting. The sling should be adjusted so that the beam or girder will remain horizontal during its transfer from the ground to its position in the structure. The hooks should be taken around the beam in opposite directions when the sling is attached. This will keep the web vertical during the transfer of the beam. Beam erection is illustrated on Page 279.

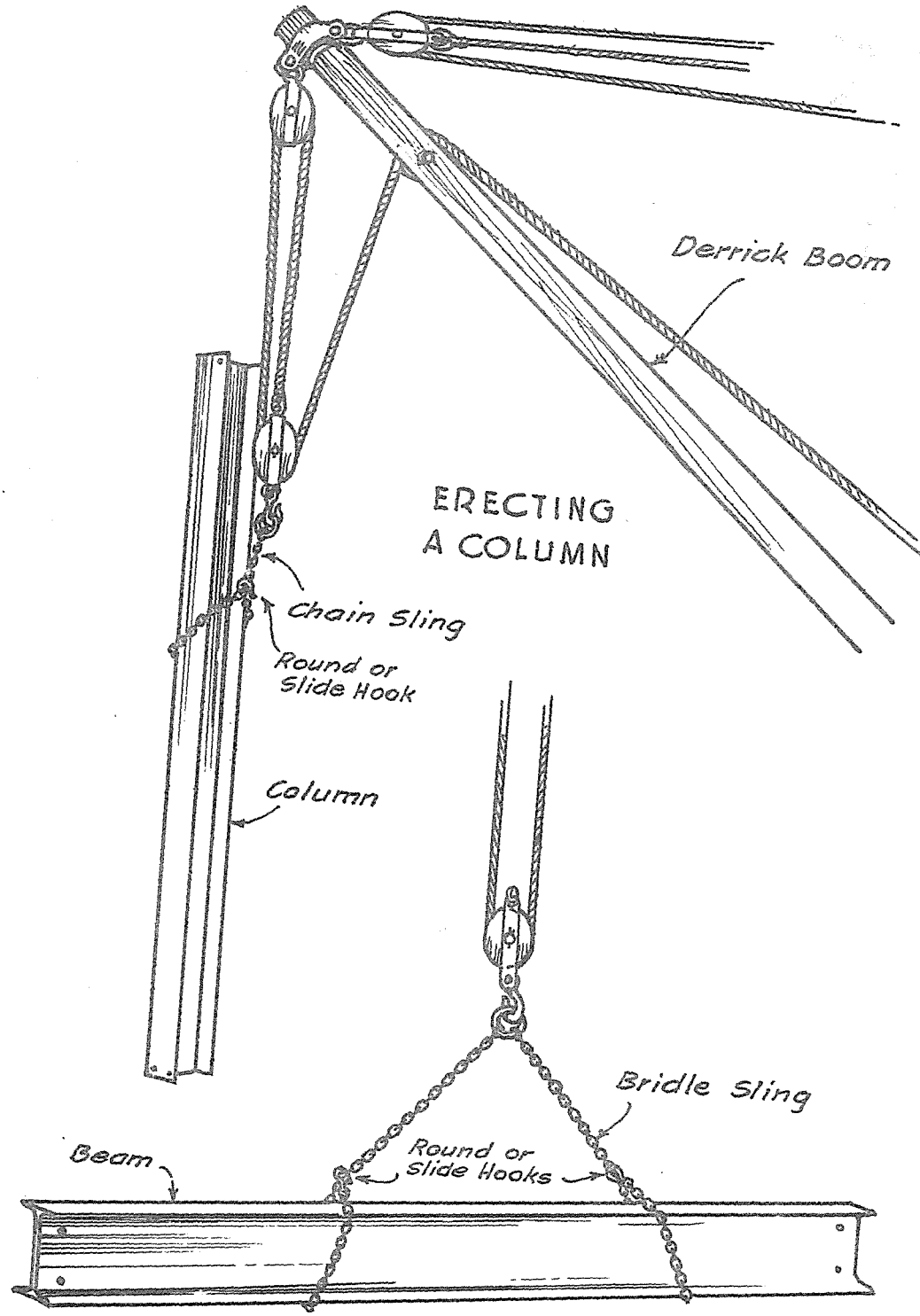
When erection is being done with a guy derrick, the steel farthest from the derrick should be placed first so that the derrick will not be shut in until the last piece is in place.

173. Cross-bracing.

The structure should be plumbed and the column braces grouted during the erection of the vertical cross-bracing. If the structure has been properly fabricated and set on a level foundation it will be plumb when the bracing is placed and bolted.

The work of erecting the cross-bracing is comparatively simple. A sling of manila rope is generally used to handle it.

If the rivet holes in the braces and the column connections do not match, the structure should be pulled into line by the use of hoisting tackle, jacks or turnbuckles.



ERECTING A GIRDER

174. Erection of Roof Trusses.

A roof truss is usually more conveniently erected if it is bolted or riveted together. If the truss does not come in one piece it should be connected on the ground. It may be erected by the use of a gin pole or a guy derrick if other means are not available. The lifting sling should be fastened to the top chord, either at the peak or at joints. Slings must not be fastened to members between the joints. Light trusses may be reinforced by lashing stiff timbers along their sides to prevent sidewise bending.

Rigidity is given to the entire roof system by the top and bottom chord braces. These are erected after the trusses and vertical braces have been placed.

Purlins and braces may be conveniently lifted by a small line equipped with a hook or shackle which is inserted in the end connection holes.

175. Plumbing of Structures.

Structures may be lined up and plumbed while the vertical bracing is being placed. If it is necessary to move a main member after it is in place, the moving should be done with jacks so set that they will not distort the member being moved.

The column bases must be brought into line before a building frame is plumbed. Columns should be tested for plumb by means of a heavy plumb bob on a long line. The column bases may be grouted as soon as the structure has been brought into a vertical position.

176. Steel Bridges.

Great care should be exercised to maintain the camber during the erection of bridge trusses. This may be accomplished by laying down the lower chord to a greater camber than specified, with such subsequent lowering as may be necessary to effect closing of the upper chord.

Bridge steel should be handled so that the members will not be bent or distorted. The members should not be hammered because of the possibility of injury to them. Straightening of the plates and angles should be carefully done and the members should then be inspected for fractures. If a fracture is indicated, the piece should be discarded. Welding of bridge steel will not be permitted. If a member is heated during the straightening process, the heating should not be to a higher temperature than that which produces a dark cherry-red color. After heating, the metal should be cooled as slowly as possible.

Material which is to be stored should be placed on skids and kept clean and properly drained. Long members should be supported on skids set close enough together to prevent injury by deflection. Girders and beams should be placed on edge and shored to prevent overturning.

Masonry bearing plates should be set level in exact position with a full and even bearing upon the bridge seat. When indicated on the plans, the plates should be set on red lead and canvas.

Anchor bolts should be accurately placed, and the nuts on anchor bolts at the expansion end must be adjusted to permit free expansion and contraction.

177. Riveting.

The rivet holes must be brought into alignment before any rivets can be driven. This can be done by driving drift pins into the holes to bring them into line. Drifting should be done only to bring the members into position. Care must be taken to prevent enlarging the holes or distorting the metal. If a hole must be enlarged to admit the rivet, it should be reamed. When rivet holes are grossly mis-matched, the defective member or members should be rejected. Drifting of mis-matched holes must not be permitted.

Fitting-up bolts and washers should be used to draw the members tightly together. The bolts are taken out as the riveting progresses and rivets are inserted in the holes. Fitting-up bolts should have square heads and nuts.

A drift pin should be driven through each hole before the rivet is inserted. This clears the hole by removing burrs and paint. The drift pin should be of the same diameter as the hole, which is one-sixteenth inch larger than the rivet to allow for swelling of the hot rivet. One end should have a long taper and the other a blunt taper.

A riveting gang usually consists of four men; two riveters, a rivet heater, and a bucker-up. The rivet heater heats the rivets in the forge and tosses them one at a time as needed, to one of the riveters. Before tossing the rivet, the heater knocks it against the forge to remove the scale. The riveter who catches it raps it against the steel work to again remove the scale and then inserts it into the hole. The bucker-up presses the rivet home with the dolly bar and holds it in place while the second riveter forms the head on the other end of the rivet.

Rivet heating requires experience and skill. The rivet heater must not only be able to heat the rivets to the right temperature without burning them, but must also be able to toss them accurately through the air to the riveter. The latter is provided with a can or pail for catching them. The can is cone shaped and the small end of the cone is flattened so that the rivet becomes wedged and can be conveniently picked out with the tongs.

After being driven, rivets should be inspected for imperfections. Loose and burned rivets are the principal flaws in rivet work. Burned rivets may be located by their appearance. Loose rivets may be found by tapping each rivet with a hammer or other steel object.

CHAPTER XVIII - RIGGING

178. General.

It is the intent of this chapter to give data on the various types of rope tackle and rigging equipment which are used for handling materials on construction jobs.

179. Manila Rope.

Ropes used on construction work are usually made of manila hemp. They are of either 3 or 4 strands. A 4 strand rope is more pliable, but is also more liable to kink. Manila rope should always be coiled clock-wise to prevent kinking. When it is to be uncoiled, the end first laid down should be pulled up through the eye of the coil. The following table gives the strengths of manila rope based on a safety factor of 4. The table is for new rope and is based on strengths adopted by rope manufacturers and other authorities. Allowance should be made in the use of the strength table for deterioration of the rope due to weather, age, abuse and other cause. A quick computation of the safe load in tons which a manila rope will carry, may be found by squaring the diameter in inches. Thus the safe load on a 3/4 inch rope is 3/4 x 3/4 = 9/16 tons = 1125 lbs.

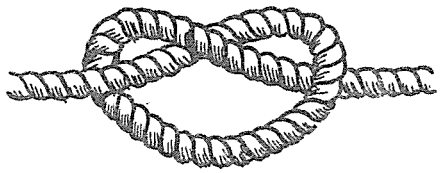
STRENGTH OF MANILA ROPE

Circumference, inches	Diameter, inches	Breaking load, pounds	Safe load, pounds
1-1/2	1/2	2,000	500
2-1/4	3/4	4,000	1,000
2-3/4	7/8	6,000	1,500
3	1	8,000	2,000
3-1/2	1-1/8	10,000	2,500
4	1-1/4	12,000	3,000
4-1/4	1-3/8	14,000	3,500
4-3/4	1-1/2	16,000	4,000
5-1/2	1-3/4	24,000	6,000
6	2	30,000	7,500

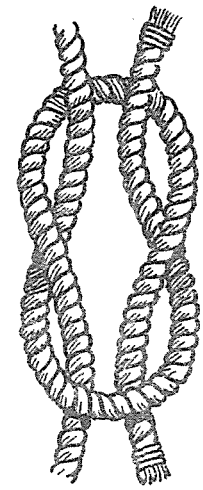
A. Knots and Hitches.

For the proper handling of rope it is very essential to have a knowledge of the various knots and hitches which may be used. If they are properly made they will not slip when under strain, and can be quickly and easily unfastened. The two most useful knots are the

overhand knot and the square, or reef knot, which are illustrated below:



OVERHAND



SQUARE OR REEF

The overhand knot is used at the end of a rope to prevent unraveling, or to prevent the end of the rope from slipping through a block.

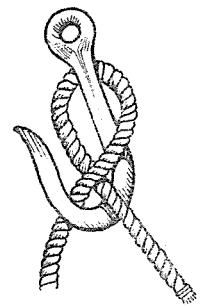
The square or reef knot is commonly used for joining two ropes of the same size. The standing and running parts of each rope must pass through the loop of the other in the same direction. The knot can be upset by taking one end of the rope and its standing part and pulling it in opposite directions. With dry rope, a square knot is as strong as the rope, but with wet rope, it slips before the rope breaks.

The parts of a rope, together with various hitches and knots, are illustrated on page 285. Other hitches and two types of guy anchors are illustrated on page 286.

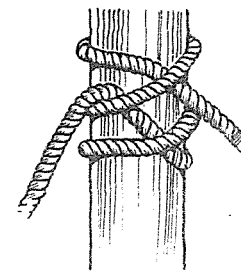
B. Lashings.

Lashings are often necessary for making the connections illustrated on page 287. The most commonly used lashing is that for a pair of shears. The two timbers for the shears are laid alongside of each other with their butts on the ground, and with the points below where the lashing is to be made, resting on a skid. A clove hitch is made around one timber and the lashing is taken loosely 8 or 9 times about the two timbers above the hitch without riding. Two frapping turns are then taken between the spars, and the lashing is finished off with a clove hitch above the turns on one side of the timbers. The butts of the timbers are then opened out and a sling is passed over the fork, to which the block is hooked or lashed. The fore and back guys are made fast with clove hitches to the bottom and top timbers respectively, just above the fork.

ROPE PARTS

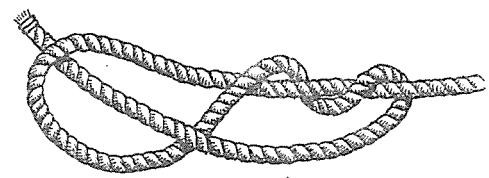


BLACKWALL HITCH

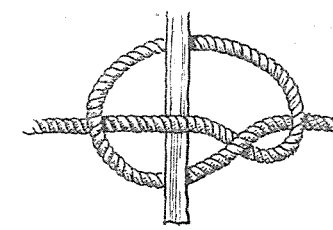


ROLLING HITCH

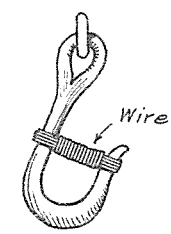
BOWLINE



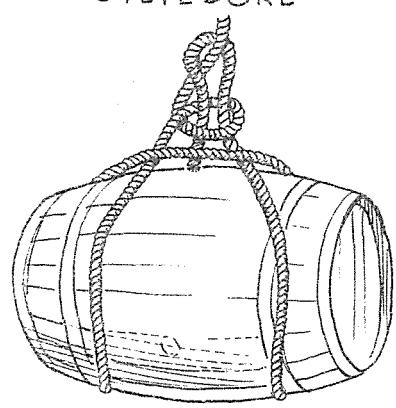
STEVEDORE



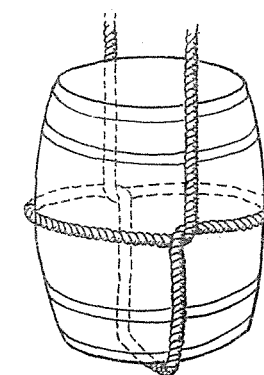
MARLINSPIKE



MOUSING

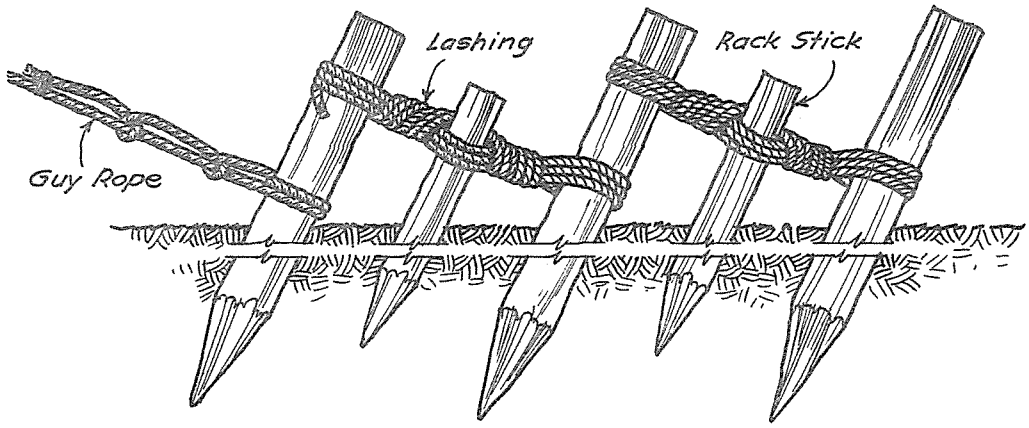


BARREL SLINGS

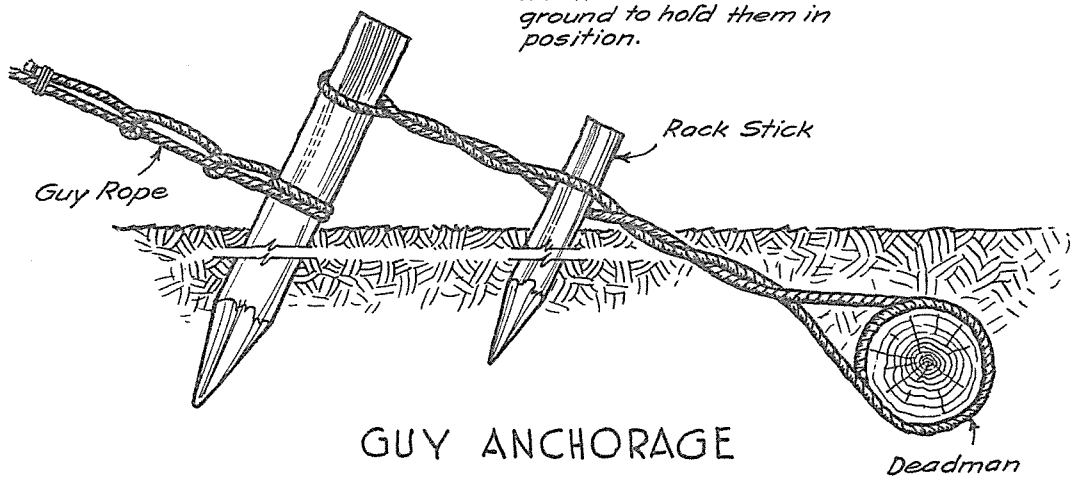


EYE FASTENERS

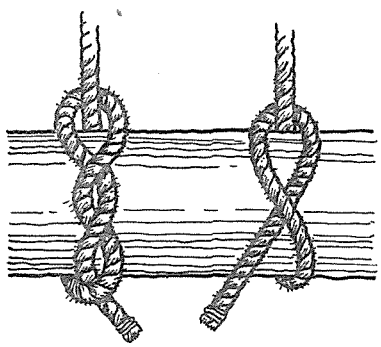
KNOTS



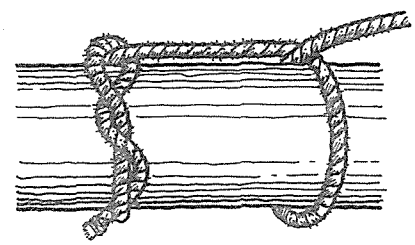
Lashings are tightened by rack sticks, the points of which are driven into the ground to hold them in position.



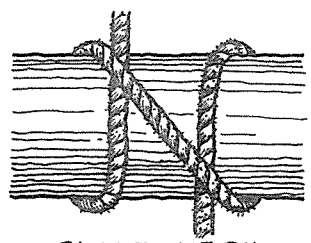
GUY ANCHORAGE



TIMBER HITCH

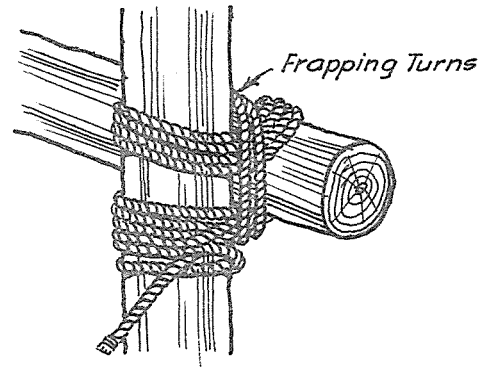


TIMBER HITCH AND HALF HITCH

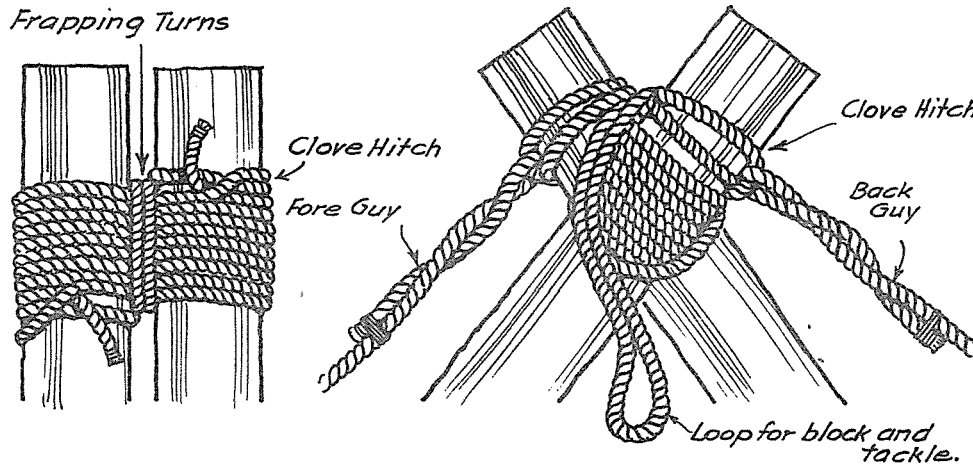


CLOVE HITCH

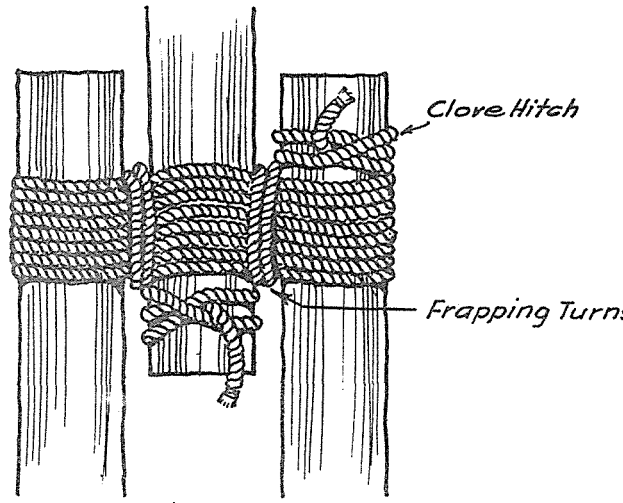
HITCHES AND ANCHORS



SQUARE LASHING



LASHING FOR A PAIR OF SHEARS



LASHING FOR A TRIPOD OR GIN

LASHINGS

180. Wire Rope.

A wire rope is usually composed of 6 or 8 strands and each strand is made up of several wires. The number of strands of wire is indicated by numbers. For example, a 6 x 7 wire rope has 6 strands, each composed of 7 wires, and a 6 x 19 wire rope has 6 strands, each composed of 19 wires. The more commonly used wire ropes have the following number of strands and wires:

5 x 19	6 x 19	6 x 29	6 x 41
6 x 7	6 x 21	6 x 33	6 x 42
6 x 8	6 x 24	6 x 36	7 x 18
6 x 12	6 x 27	6 x 37	8 x 19
6 x 17			

The flexibility of a rope is dependent upon the number of wires in each strand. The greater the number of wires, the more flexible is the rope. A 7-wire strand makes a stiff rope, which is used principally for guys. The best hoisting ropes should have strands consisting of 19 wires each.

Steel guy rope is usually galvanized for protection against corrosion, but steel hoisting rope is untreated, except for lubricants which may be applied. All wire rope has a lubricated core built into it.

Wire hoisting ropes are commonly made of "plow steel" and "cast steel". Plow steel has more strength, as shown by the following tables, which were developed by the American Steel and Wire Company, using a safety factor of 5. The safe loads that may be applied to wire rope are approximately 6 times that which may be applied to manila rope of the same size, i.e., safe load in tons = diameter inches squared times 6.

STRENGTH OF STANDARD WIRE HOISTING ROPE

Diameter, inches	Breaking load, lbs.	Safe load, lbs.
CAST STEEL - 6 x 19 HEMP CENTER		
3/8	9,000	1,800
1/2	15,400	3,080
5/8	23,600	4,720
3/4	33,600	6,720
7/8	45,600	9,120
1	59,000	11,800
PLOW STEEL - 6 x 19 HEMP CENTER		
3/8	10,000	2,000
1/2	17,000	3,400
5/8	26,200	5,240
3/4	37,400	7,480
7/8	50,800	10,160
1	66,000	13,200

It is preferable to use reels for handling wire rope, but if reels are not available, the wire may be coiled. Wire rope can be coiled or uncoiled in only one way if kinks are to be prevented, and that one way is to roll the coil on the ground like a hoop for both operations.

181. Rope Tackle.

The arrangement of the tackle is the same for both manila and wire rope. The term includes the ropes, blocks, and hooks which are used for hoisting. Hoisting tackle and slings are illustrated on page 291.

The parts of a block are the shell or frame, the sheave or wheel upon which the rope runs, and the pin on which the wheel turns in the shell. A strap of iron passes around the shell to form attachments for a hook at one end and an eye at the other. The strap is replaced by bolts for metal blocks. Wooden blocks are usually used with manila rope, while metal blocks are usually used with wire rope.

A snatch block is a single block with the shell and strap open on one side to admit a rope.

The strength of the body of a tackle block is usually greater than that of the rope which is used with it. The hook is generally the weakest part of the block, because it has a tendency to open out when subjected to a heavy load. Blocks intended for heavy work should be fitted with shackles. Shackles are much stronger than hooks of the same size, as shown by the following tables, which are based on a safety factor of 5:

SAFE LOAD ON HOOKS

Diameter of metal in inches	Breaking load, pounds	Safe load, pounds
3/4	3,500	700
7/8	5,000	1,000
1	7,500	1,500
1-1/16	10,000	2,000
1-3/8	15,000	3,000
1-7/16	20,000	4,000
1-5/8	25,000	5,000
1-7/8	30,000	6,000
2	37,500	7,500

SAFE LOAD ON SHACKLES OR SOCKETS

Diameter of Metal in inches	Breaking load, pounds	Safe load, pounds
3/4	37,500	7,500
7/8	50,000	10,000
1	70,000	14,000
1-1/8	82,500	16,500
1-1/4	87,500	17,500
1-3/8	90,000	18,000
1-1/2	110,000	22,000
1-5/8	137,500	27,500
1-3/4	150,000	30,000
1-7/8	170,000	34,000
2	210,000	42,000

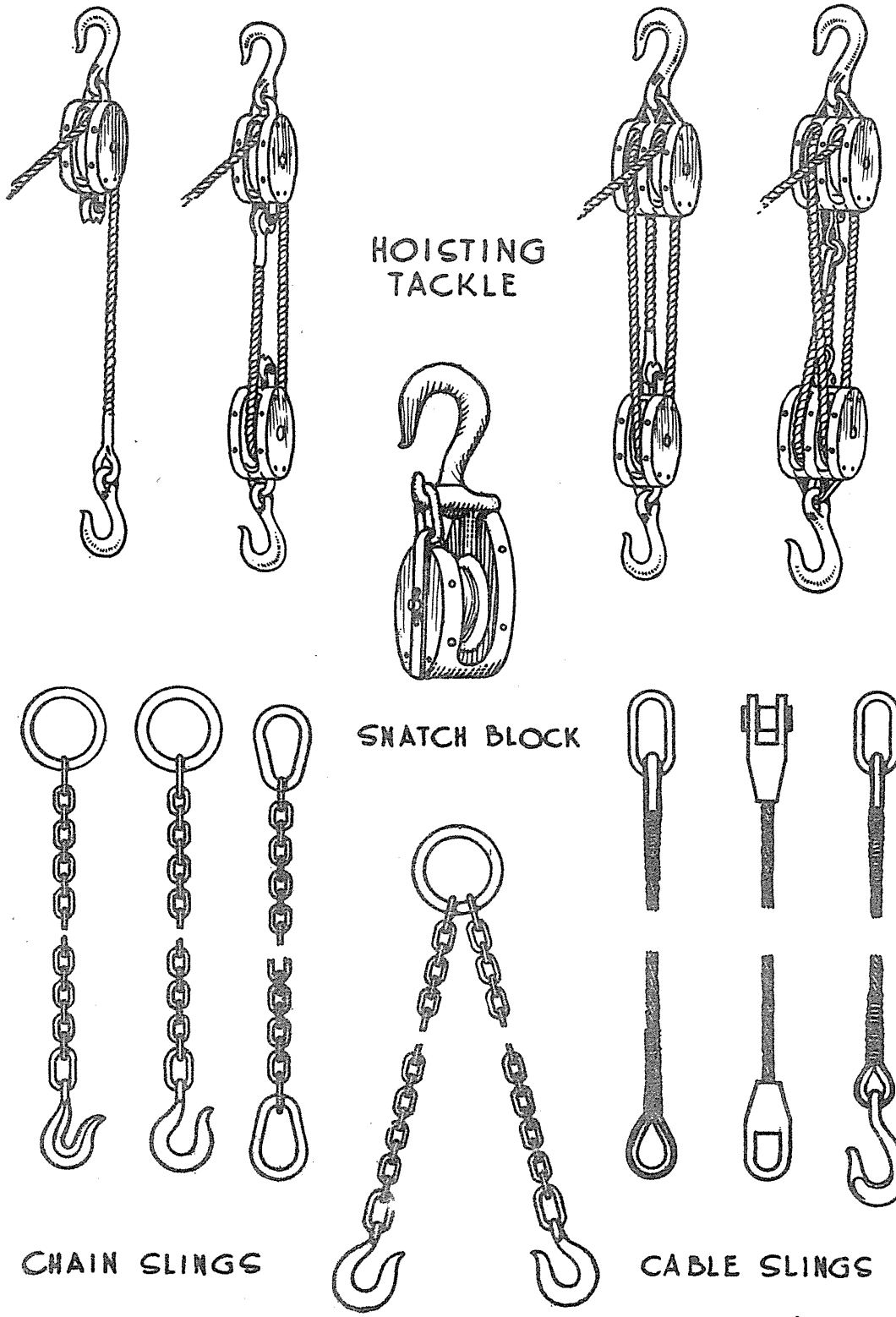
During the hoisting operation, each part of the rope, progressing from the bucket toward the fall end or lead line, has to overcome an increasing amount of friction. Each block through which the rope passes adds a certain amount to the friction which must be overcome. Snatch blocks and additional sheaves outside of the hoisting tackle over which the fall end passes, cause still further loss of power. The net lifting capacity of the tackle then depends on the strength of the lead line which remains after deducting the pull necessary to overcome friction.

This assumption is based upon the other parts of the tackle being sufficiently strong. The table on page 292 giving the safe lifting capacity of tackle takes the friction losses into account.

The internal friction in a rope and the possibility of breaking the wires will be less with each increase in size of the sheave. The capacity of any block can be determined by computing the strength of the pin and the straps that support the sheaves. The following table gives the recommended sheave and drum diameter for use with wire rope:

Wire Rope Size	Average Sheave or Drum Size	Minimum Sheave or Drum Size
6 x 7	72 times rope diameter	42 times rope diameter
6 x 19	45 " " "	30 " " "
6 x 37	27 " " "	18 " " "
8 x 19	31 " " "	21 " " "

The maximum sheave diameters for use with manila rope should be 6 times the diameter of the rope.


HOISTING TACKLE
SNATCH BLOCK
CHAIN SLINGS
CABLE SLINGS
BRIDLE SLING

TACKLE

SAFE LIFTING CAPACITY OF TACKLE WITHOUT SNATCH BLOCKS

NEW MANILA ROPE

Size Rope inches	Diameter Sheaves inches	Total No. of sheaves	Safe lifting capacity pounds
3/4	7	2	1500
"		3	2000
"		4	2800
"		5	3500
"		6	4000
1	10	2	2000
"		3	4000
"		4	6000
"		5	8000
"		6	10000
1-1/4	12	2	4000
"		3	7000
"		4	10000
"		5	12000
"		6	14000
"		7	16000
1-1/2	14	2	8000
"		3	10000
"		4	13000
"		5	17000
"		6	20000
"		7	23000

WIRE ROPE

Where snatch blocks are used, in the lead line, deduct 10% to 15% from the capacity for each block so used

Size Rope inches	Diameter Sheaves inches	Total No. of sheaves	Safe lifting capacity pounds
1/2	10	2	8000
"		3	10000
"		4	14000
"		5	18000
"		6	20000
"		7	22000
5/8	12	2	12000
"		3	16000
"		4	22000
"		5	26000
"		6	30000
"		7	34000
3/4	14	2	16000
"		3	24000
"		4	32000
"		5	38000
"		6	44000
"		7	50000

182. Chains.

Chains are widely used as slings for hoisting heavy construction materials. Chains smaller than 1/2 inch are usually made of mild open-hearth steel and are electrically welded. Chains larger than 1/2 inch are usually made by hand-welding wrought iron bars. Bending and welding reduces the strength of a chain so that it is not twice but only about 1.5 to 1.7 times as strong as the original bar. Safe loads which may be placed on chains are shown below:

Diameter of metal inches	Safe load pounds
1/4	1,330
3/8	2,660
1/2	5,330
5/8	8,330
3/4	12,000
7/8	16,330
1	20,830

Chains which are in constant use require lubrication and frequent annealing. Hoisting chains and sling chains should be annealed at least once each year to prevent hardening and unexpected failure.

183. Chain Tackle.

Chain hoists are convenient and efficient for lifting heavy loads. They are usually complete assembled units of various rated capacities. The main advantage of a chain hoist is that while the load is being lifted it will remain suspended at any level without the necessity of anchoring or snubbing the lead line.

184. Rigging Equipment.

A. Winches.

A winch consists of a frame to which is attached a winding drum and a set of gears. A handle is attached at each end of the winding mechanism. Winches are used for hoisting heavy material and may be attached to the masts of gin poles or derricks.

Winches are designed for use with either manila or wire rope. Drums used with manila rope are usually smaller in diameter and longer than those used with wire rope. Manila rope drums average between 4 and 6 inches in diameter and are usually not less than 24 inches long. Wire rope drums average between 8 and 10 inches in diameter and have a maximum length of 20 inches.

B. Jacks.

The screw jack is the type most commonly used on construction jobs, although ratchet and hydraulic jacks are sometimes used. If the work requires than an object must be raised higher than the lift of the jack, it must be blocked after each lift and the jack moved to a higher level. Each jacking operation requires the use of timber blocking to serve as a support for the object being lifted and for the jack. Extreme caution should be used because failure of the jack or the blocks might cause serious injury to the workmen or destruction of the object being lifted.

C. Gin Poles.

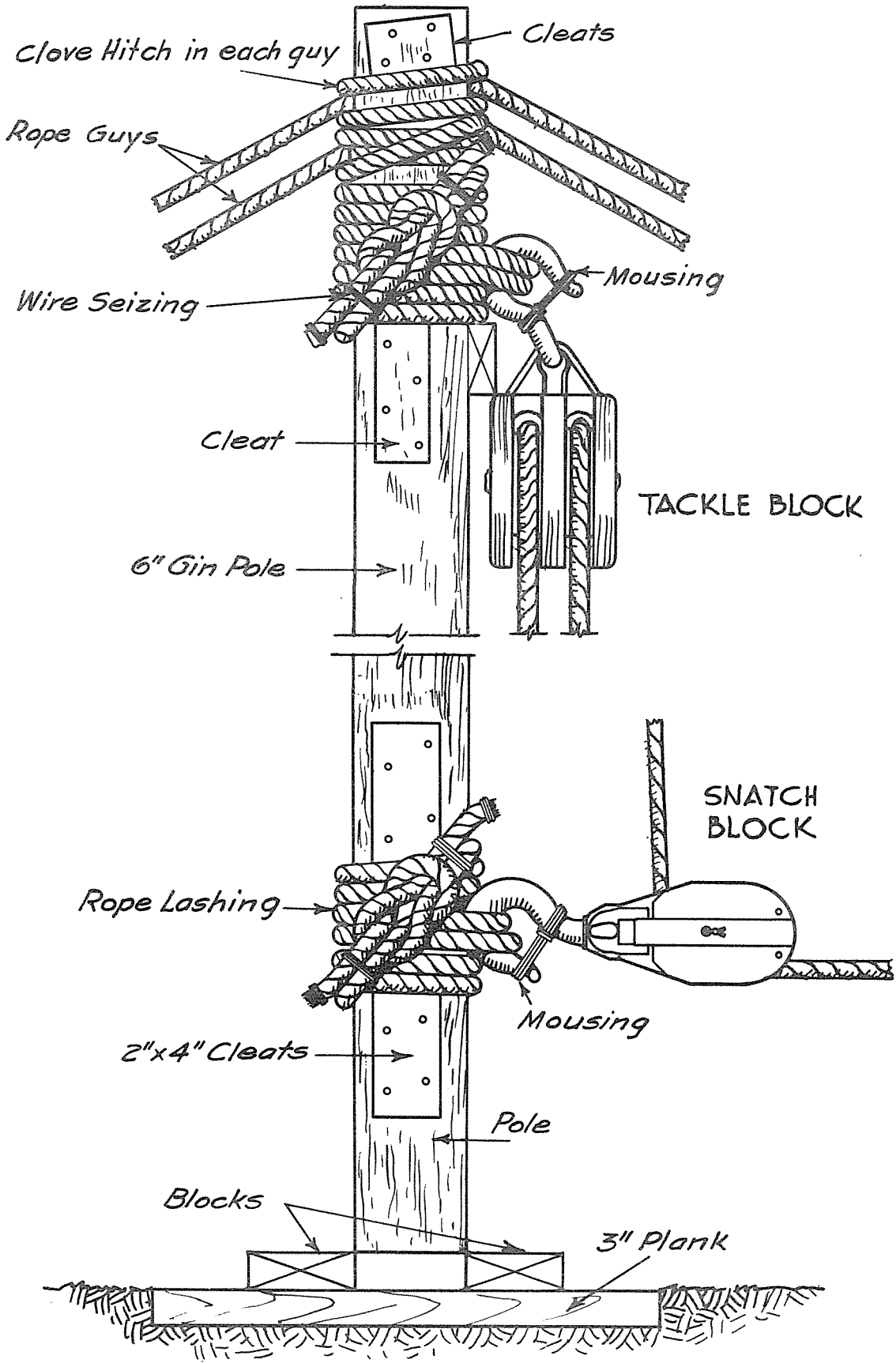
A gin pole is the most common type of rigging equipment used for lifting loads vertically. It consists of an upright pole, equipped with hoisting tackle which is properly guyed at the top so that it will maintain its upright position.

Gin poles should not be longer than 60 times their diameter because of their tendency to buckle under compression strain. Gin pole timbers should be straight and free from any serious defects. The following table gives the safe lifting capacity of spruce poles:

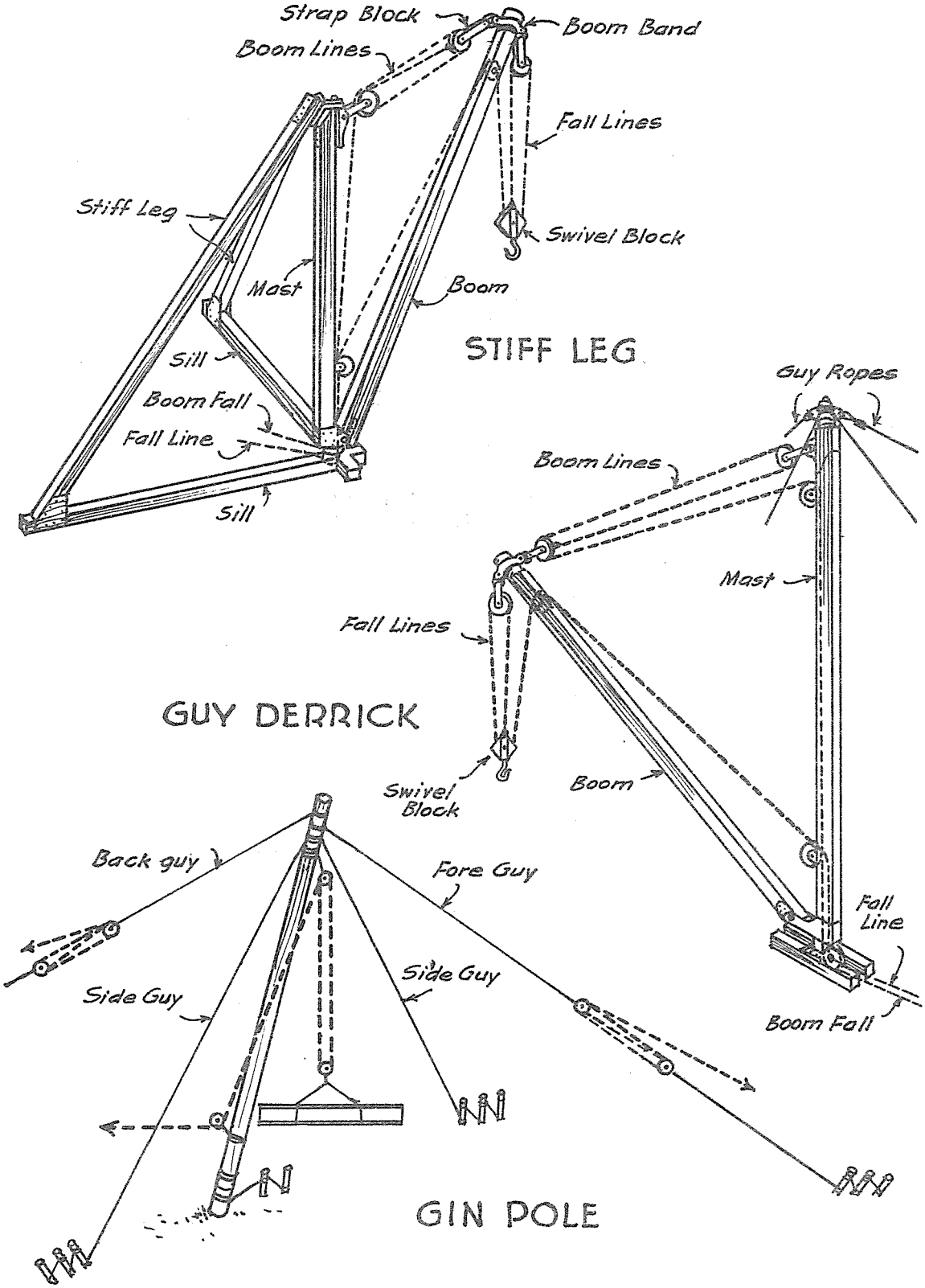
SAFE CAPACITY OF SPRUCE GIN POLES

Cross Section Dimensions Inches	Length Feet	Safe Lifting Capacity Pounds
6 x 6	20	12,000
6 x 6	25	8,000
6 x 6	30	4,000
8 x 8	25	30,000
8 x 8	30	22,000
8 x 8	35	16,000
8 x 8	40	10,000
8 x 8	45	4,000
10 x 10	25	56,000
10 x 10	30	48,000
10 x 10	35	36,000
10 x 10	40	30,000
10 x 10	45	22,000
10 x 10	50	14,000
12 x 12	30	76,000
12 x 12	40	56,000
12 x 12	50	36,000
12 x 12	60	16,000

A gin pole should be rigged as shown in the illustration on page 295. All work should be done with the pole laying flat on the ground. After the top tackle lashings, the lower snatch block lash-


Clove Hitch in each guy
Cleats
Rope Guys
Mousing
Wire Seizing
Cleat
TACKLE BLOCK
6" Gin Pole
SNATCH BLOCK
Rope Lashing
Mousing
2"x4" Cleats
Pole
Blocks
3" Plank

GIN POLE



RIGGING EQUIPMENT

ings, and the upper guy attachments have been made, the pole should be raised on its footing blocks to the proper operating position as shown in the illustration on page 296.

D. Shears.

Shears are particularly adapted for lifting heavy loads, but considerable time is required for the various operations necessary for proper rigging. The lashing operations are described in Article 179-B. After the shears have been erected the legs may be prevented from spreading by the use of a single rope lashing attached to the legs just above the ground.

E. Derricks.

(a) Guy Derricks.

A pole or guy derrick is essentially a gin pole constructed with a sill and having knee braces at the bottom. It is frequently equipped with a sheave inserted in the upper portion of the mast. The sill and braces give the derrick stability in two directions, so that usually only one front guy and one rear guy are necessary. Additional guys may be used if required. A simple guy derrick is illustrated on page 296.

The pole derrick may be used to good advantage where a gin pole might also be used. This is especially true where the work requires that the pole be moved frequently, as in the setting of girders and beams in wooden mill buildings. One chief advantage is the facility with which it may be shifted from place to place. The guy derrick is not practical for extreme heights of poles since it is heavy and hard to handle in the larger sizes. It is particularly adapted to lighter erection work such as the setting of steel girders trusses, purlins, etc. which do not have to be placed too high above the ground.

The ordinary type of pole derrick is too light to withstand the pull of a snatch block when a steam engine or a crab winch is used to furnish power for lifting heavy loads. The necessity for additional strength has led to the development of a heavier type of guy derrick called a "monkey". A monkey derrick consists of a mast which is braced in three directions to prevent overturning and which is given a slight forward tilt. Two back guys are usually required when heavy loads are lifted. The principal use of a monkey derrick is in the erection of columns in structural steel work.

(b) Stiff-leg derrick.

The stiff-leg derrick differs from the guy derrick in the method which is used to hold the mast in a vertical position. The method of rigging is the same for both types as is shown by the illustration on page 296.

The stiff-leg derrick may be operated by hand or mechanical power. The sills should be weighted or anchored so that the derrick will not be overturned when too heavy a load is placed on the boom.

CHAPTER XIX - ROOFING MATERIALS

185. Wood shingles.

Wood shingles provide a durable and satisfactory roof for most Forest Service buildings. They give a good natural insulation to all buildings on which they are applied. The proper application provides three thicknesses of wood, and thereby gives a triple protection against heat or cold. A description of shingles is given in Article 63.

Wood shingles offer a practical and economical means of covering the walls of buildings for modernization or betterment. They may be used for covering an old roof which has previously been covered with wood or composition shingles. It is not necessary that the old covering be removed, and considerable expense in labor costs can thus be saved. A double roof gives even greater insulation than a single roof.

Shingles should be attached with copper nails or wire nails which have been coated with zinc by the hot dipping process. Ungalvanized or blued nails should never be used, because they will rust out long before the shingles need replacing.

A. Sizes and Grades.

Cedar shingles are manufactured in three standard lengths, 24 inches, 18 inches, and 16 inches. Each length is divided into three grades. A description of each length and grade is given in the following table:

SHINGLE GRADES

Grade Name	Character of Grade and Suitable Uses
No. 1-24 inch, 4 butts to 2 inches (Formerly called No. 1 Royals)	No. 1-24 inch is the highest quality shingle. It must be entirely clear, of edge grain, and all heartwood. Thick butts assure deep shadow lines. When properly laid with rust resisting nails, this grade will give service for a lifetime. This grade conforms to United States Department of Commerce Commercial Standard Specifications CS31-33 and a certificate label denoting this should always be specified to appear on each bundle.

No. 2-24 inch, 4 butts to 2 inches (Formerly called No. 2 Royals)	No. 2-24 inch is as high a grade of shingles as is necessary for sidewalls, or for the undercourse of double coursing on roofs, with No. 1-24 inch shingles on top. A roof laid double with these shingles produces a combined thickness at the butts of 1 inch, and renders a beautiful depth with a wide shadow line. These shingles must be clear for 16 inches from the butt, and may not contain more than 1 inch of sapwood for 10 inches from the butt.
No. 3-24 inch, 4 butts to 2 inches (Formerly called No. 3 Royals)	No. 3-24 inch is the lowest grade manufactured in the 24 inch length shingles. Their use should be confined to temporary or cheap work such as sheds, garage side walls, etc. These shingles are clear or better for 10 inches from the butt, but may contain sapwood.
No. 1-18 inch, 5 butts to 2-1/4 inches (Formerly called No. 1 Perfections)	No. 1-18 inch is a high grade clear, edge-grain, heartwood shingle suitable for use on roofs or sidewalls. This grade conforms to the United States Department of Commerce Commercial Standard Specifications CS31-33 and a certificate label denoting this should always be specified to appear on each bundle.
No. 2-18 inch, 5 butts to 2-1/4 inches (Formerly called No. 2 Perfections)	No. 2-18 inch is a good grade for use on sidewalls or for the undercoursing of a double course on roofs, with No. 1-18 inch shingles on top. It must be clear for 12 inches and may not contain more than 1 inch of sapwood for 10 inches from the butt.
No. 3-18 inch, 5 butts to 2-1/4 inches (Formerly called No. 3 Perfections)	No. 3-18 inch is the lowest grade manufactured in the 18 inch length. It is suitable for temporary or cheap work, such as sheds, garage sidewalls, etc. These shingles are clear or better for 8 inches from the butt, but may contain sapwood.

No. 1-16 inch, 5 butts to 2 inches (Formerly called No. 1 XXXXX or No. 1 Perfects)	No. 1-16 inch is the most popular high quality shingle for all ordinary construction. Being clear and of vertical grain, it does not cup nor curl, and if properly laid will give long service. This grade conforms to United States Department of Commerce Commercial Standard Specifications CS31-33 and a certificate label denoting this should always be specified to appear on each bundle.
No. 2-16 inch, 5 butts to 2 inches (Formerly called Extra Clears)	No. 2-16 inch is suitable for sidewalls or for the undercourse of double laid roofs, with No. 1-17 inch shingles on top. It is 12 inches clear or better from butt, and may not contain more than 1 inch of sapwood for 10 inches from the butt.
No. 3-16 inch, 5 butts to 2 inches	No. 3-16 inch is the lowest grade of shingle manufactured, being of poorer quality than the former Extra Star A Star. Its use should be confined to temporary or cheap work such as sheds or garage sidewalls.

B. Flashing and Counterflashing.

Necessary flashing and counterflashing should be provided against all breaks and projections and about pipes and vents passing through the roof. All flashing and counterflashing should be of 16 oz. copper or #24 gauge galvanized iron.

Valley flashing should be not less than 20 inches wide. The flashing sheets should be lapped 6 inches longitudinally and should be without soldered connections. All sheets should have the edges under tiles turned up and back and secured in place with 1-1/2" x 3" copper cleats. The cleats should be spaced not over 12 inches apart and should be fastened to the roof boards with two copper nails each 7/8" long. No nails should be driven through the sheets. Base flashings should be approximately 10 inches high and should turn out on the roof not less than 4 inches.

Counter or cap flashings should be built into the masonry or into reglets in the walls not less than 2 inches. The end should be bent up and back on itself approximately 1/2 inch and should be secured in place with metal plugs cemented tightly. Counterflashing should extend down over the base flashing at least 4 inches, unless otherwise provided for in the plans. The lower edge should be turned back on itself for 1/2 inch. Stop flashings should be used for vertical surfaces in connection with pitched roofs.

Standard flashing methods are illustrated on Pages 303, 304, 305, and 306.

C. Re-roofing over Existing Roof.

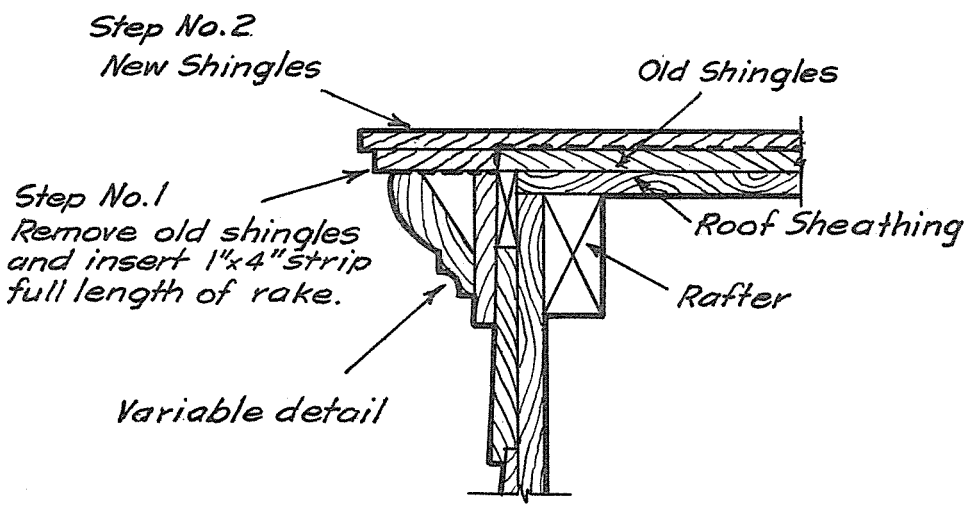
If cedar shingles are to be applied over an existing roof, the following method of procedure may be of help in doing the work:

Step #1. The old shingles should be cut away at the rake to provide space for a 1" x 4" strip which will give a solid nailing surface for the new shingles on the rake or gable edge.

Step #2. Shingles should be started with a double course at the eaves. The butts of the new shingles should overhang the old shingles for 1/2 inch to provide for drainage. Shingles should then be laid in the same manner as for a new roof.

Step #3. A strip should be nailed over the old valley to provide a solid foundation for the new valley. Flashings should be replaced around vent pipes and chimneys.

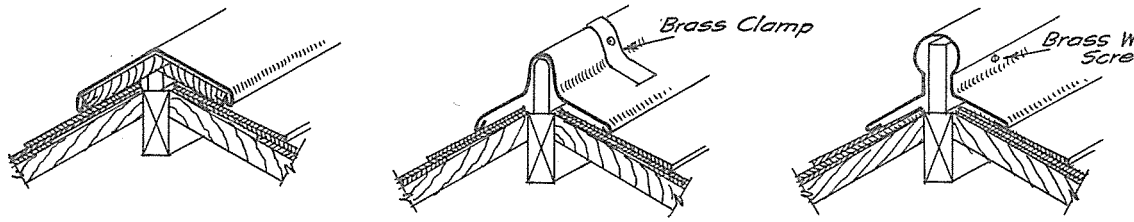
Steps #1 and #2 are illustrated below:



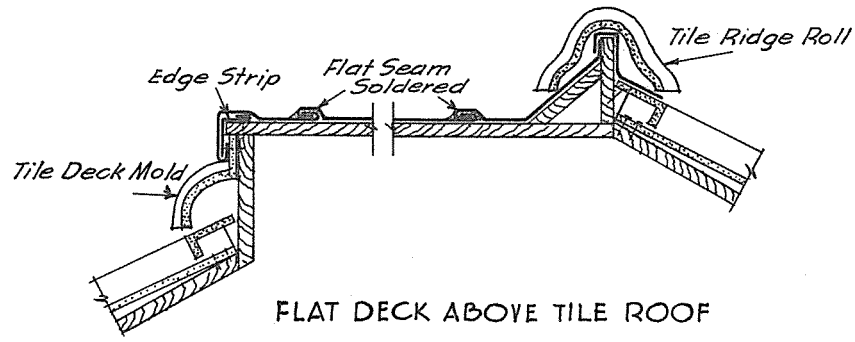
DETAIL AT RAKE OR GABLE EDGE

186. Hand-split wood Shingles or Shakes.

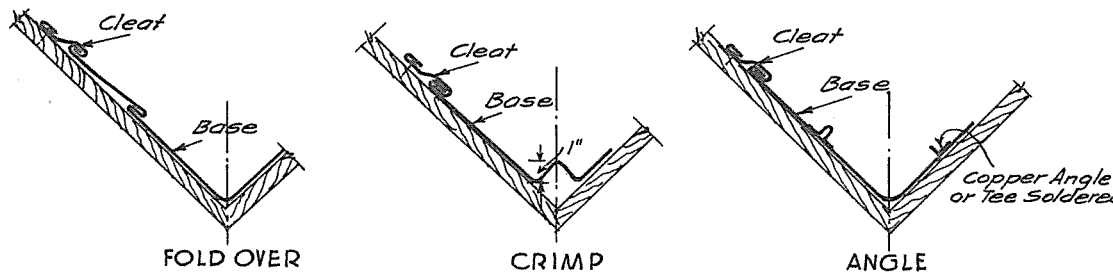
Hand-split wood shingles may be manufactured from cypress, cedar, redwood, and almost all other kinds of wood. The three mentioned are more durable than other kinds and are most commonly used. Shakes should be edge-grained and free from knots, sap or other imperfections. They should be from 18 inches to 31 inches long and have random widths of from 5 to 10 inches, with random butt thicknesses of not less than 1/2 inch.



HIP OR RIDGE FLASHING

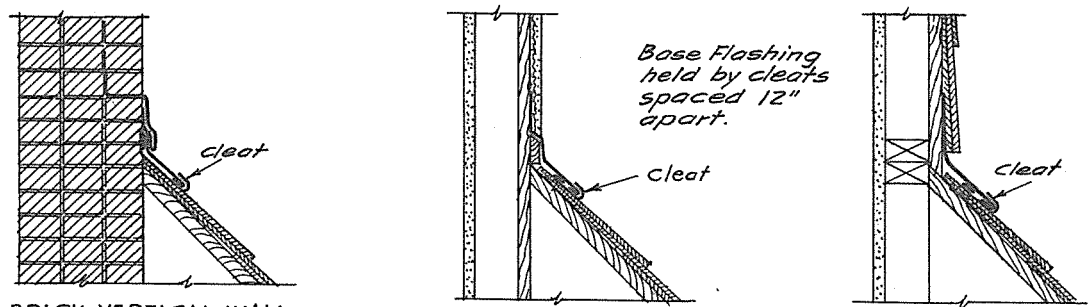


FLAT DECK ABOVE TILE ROOF



FOLD OVER CRIMP ANGLE

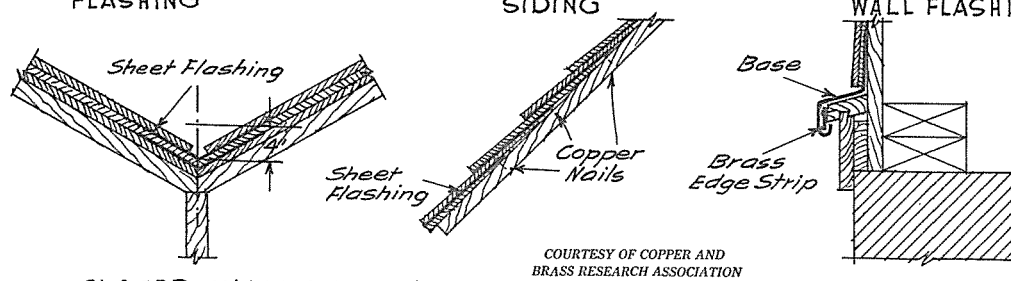
VALLEY FLASHING



BRICK VERTICAL WALL FLASHING

STUCCO ON WOOD SIDING

SHINGLED VERTICAL WALL FLASHING

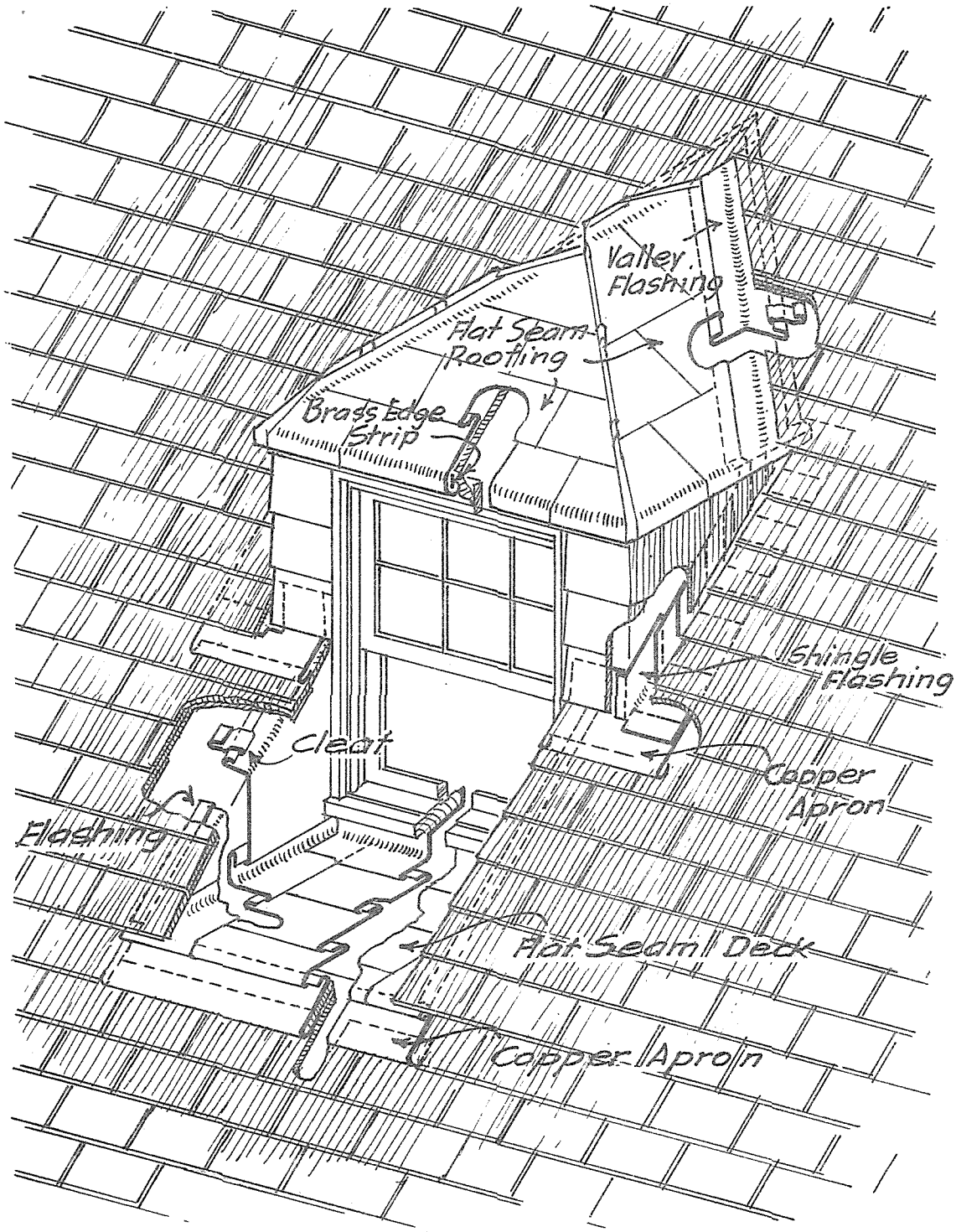


CLOSED VALLEY (Sheet)

COURTESY OF COPPER AND
BRASS RESEARCH ASSOCIATION

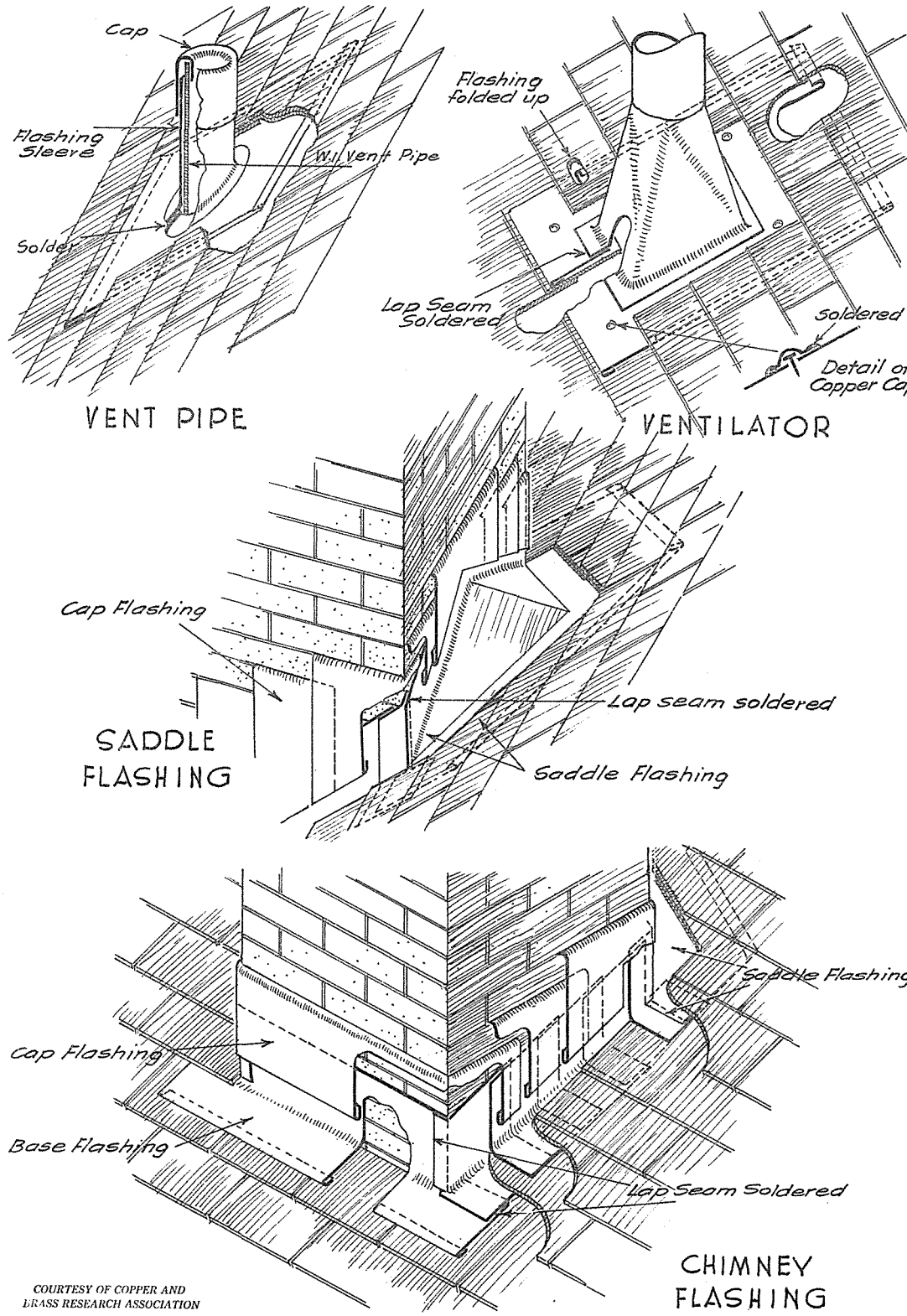
WATER TABLE

FLASHING



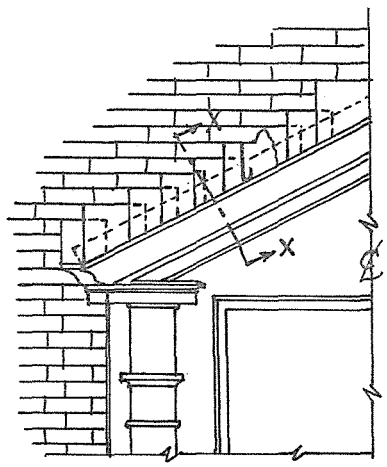
COURTESY OF COPPER AND BRASS RESEARCH ASSOCIATION

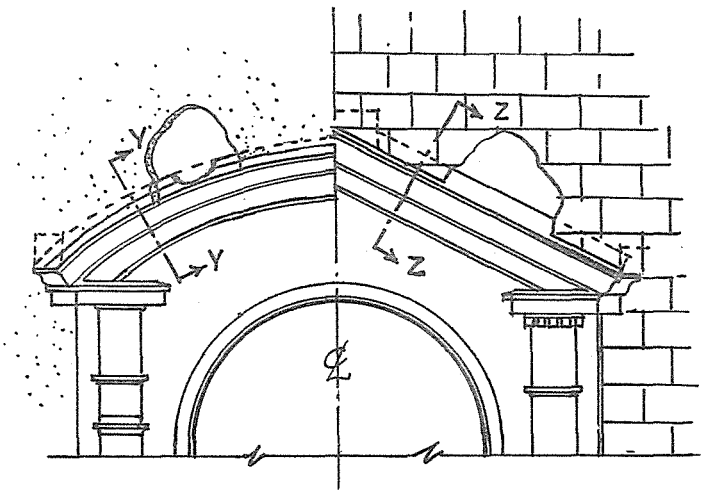
DORMER WINDOW AND RECESS FLASHING

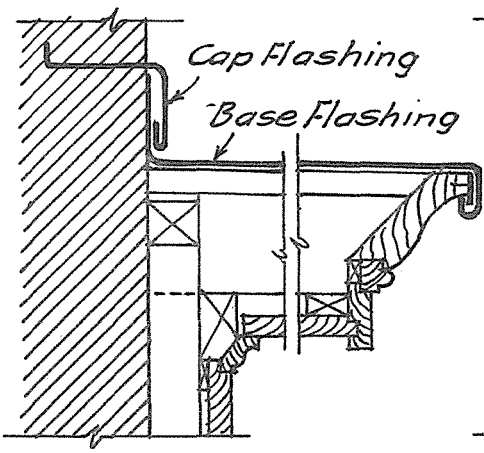


COURTESY OF COPPER AND BRASS RESEARCH ASSOCIATION

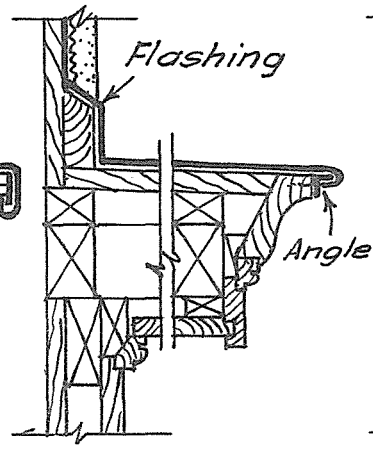
CHIMNEY AND ROOF FLASHING



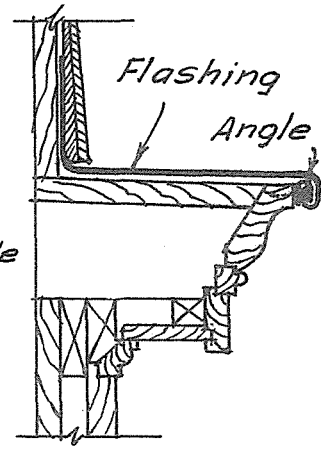




SECTION X-X

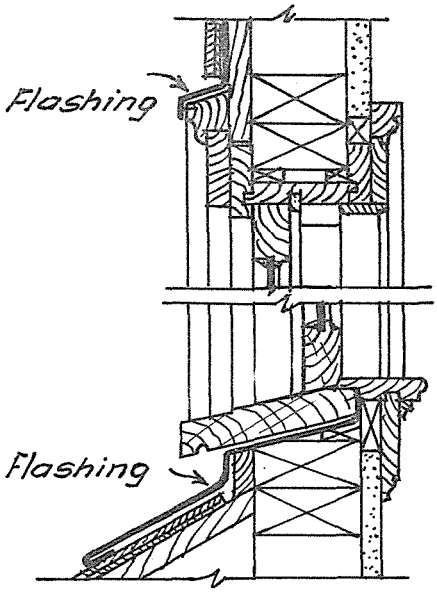


SECTION Y-Y



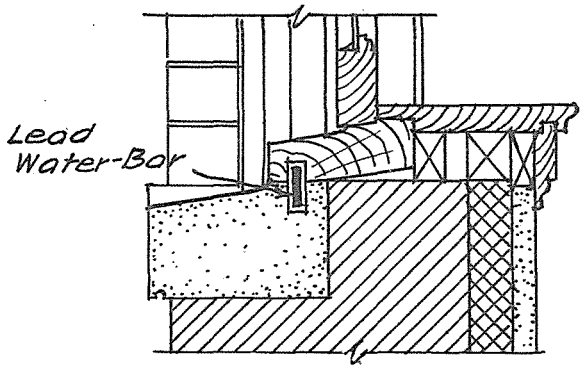
SECTION Z-Z

DOORWAYS



DORMER WINDOW

COURTESY OF COPPER AND BRASS RESEARCH ASSOCIATION



WATER BAR IN STONE SILL

WINDOW AND DOOR FLASHING

A. Stock.

Cedar or redwood shakes may be split from either green or dead timber. Sapwood should never be used because of its susceptibility to rotting. Windfall timber may be used and it will give good service. The heartwood of all trees provides the best shake material.

B. Method of Cutting Bolts.

When bolts are cut for shakes, particular care should be exercised in making each cut square with the grain of the wood. This precaution will insure rectangular shakes of uniform length. All rotten wood and other unsuitable material should be trimmed away before the bolts are split. The log-cuts should be split into quarters and then subdivided into bolts which will produce the maximum number of vertical grain shakes. Shakes should average about 8 inches in width. Those wider than 8 inches have a decided tendency to curl and split. Good practice requires that shakes wider than 8 inches be split before they are laid. Bolts should be carefully shaped to prevent waste. The center portion of the log-cut should be discarded to avoid flat grain and defects.

C. Shake-making Tools.

(a) Froe.

The froe or tool used for splitting the shakes is illustrated on page 308. It should be properly constructed and must be kept sharp to insure ease in handling and efficiency in operation. The flat surface of the froe blade should always be faced toward the bolt.

(b) Mallet.

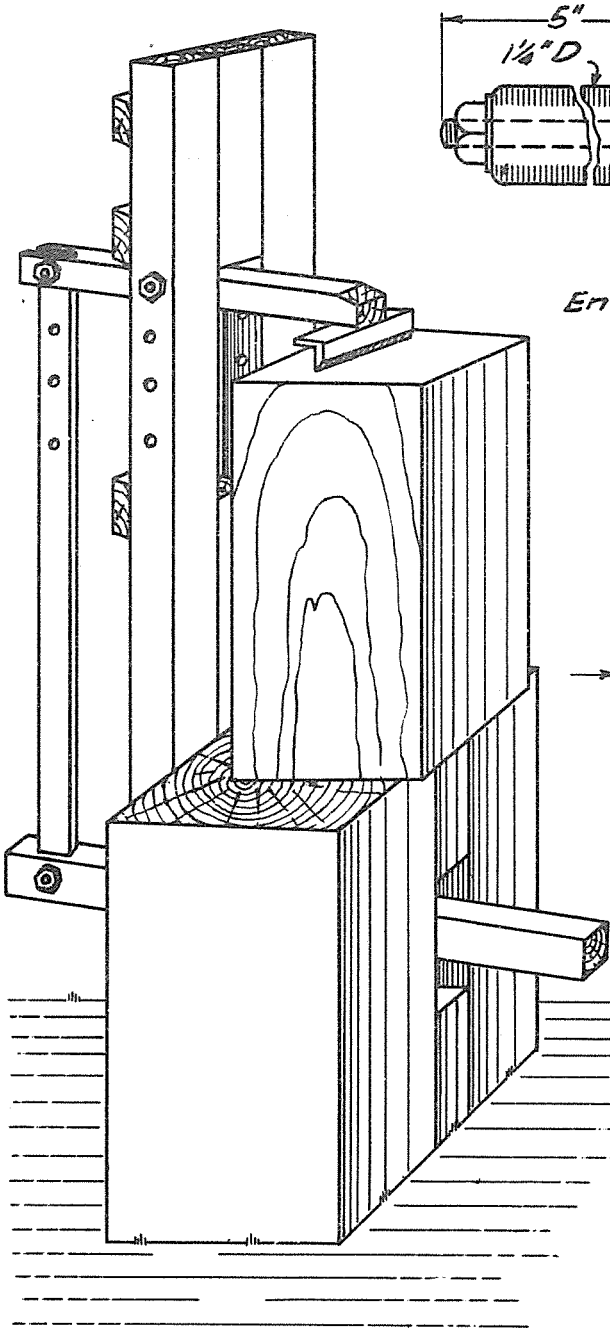
The mallet used for driving the froe is illustrated on page 308. It should be constructed of dead maple burl or the tough roots or limbs of trees that do not splinter easily. Metal mallets should never be used.

(c) Splitting Block.

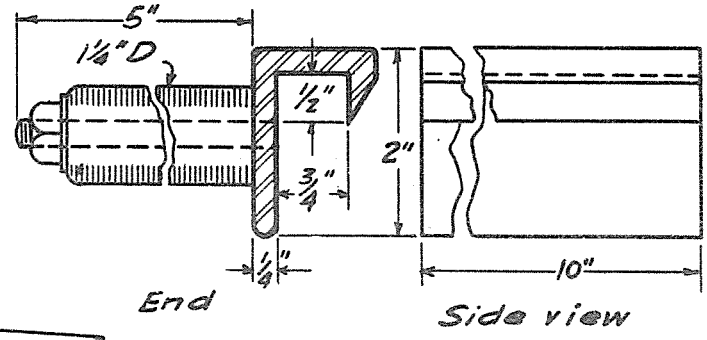
The splitting block should have a flat level surface and should be partially imbedded in the earth so that it will not move while it is being used. It should be placed in a convenient position so that the operator will be sure of a firm, solid foundation for the bolt from which the shakes are to be split.

(d) Jack.

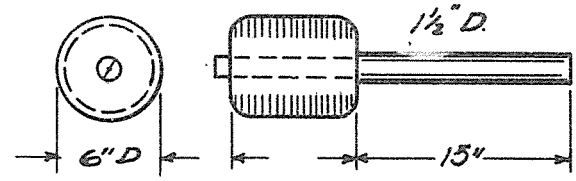
The jack is used to hold the shake-bolt firmly in position to expedite production. Its use leaves the operator with both hands free so that he may handle the froe and mallet. A jack is illustrated on pages 308 and 310.



SPLITTING TABLE
AND SHAKE BOLT JACK

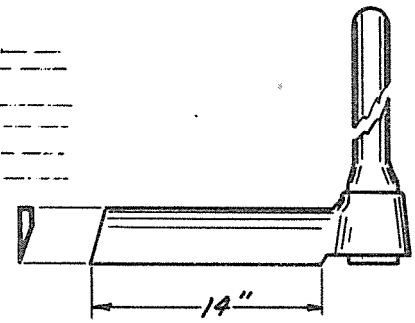


THICKNESS GAUGE



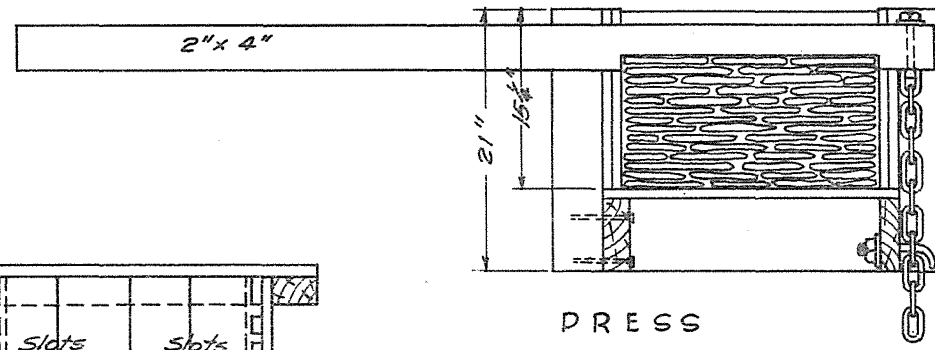
MALLET

Head of maple burl or tough Root wood.

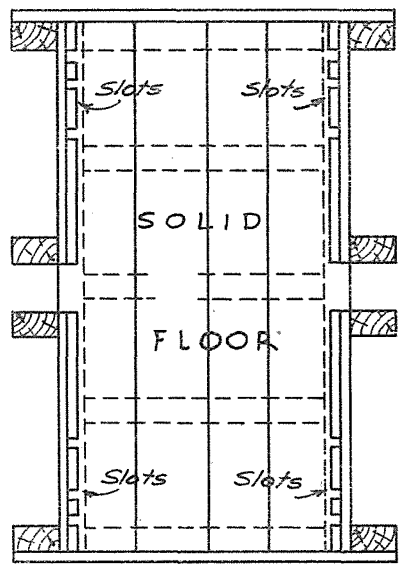


FROE

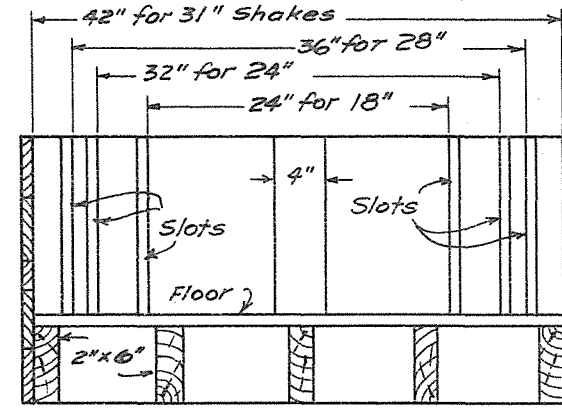
TOOLS FOR MAKING SHAKES



PRESS

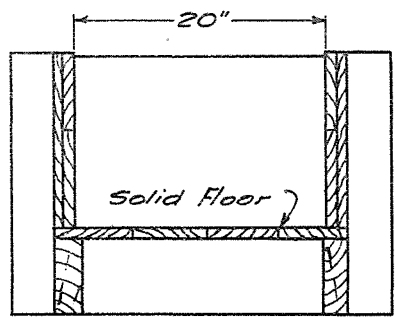


PLAN

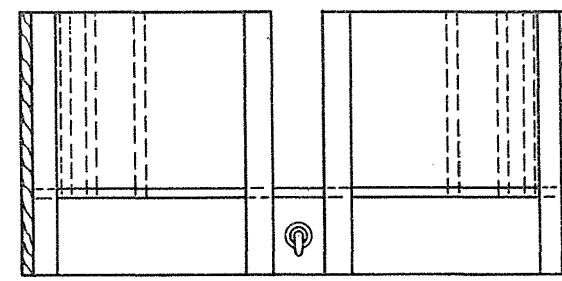


INSIDE VIEW

Showing Slots for Placing Stop Boards to lay shake butts against.

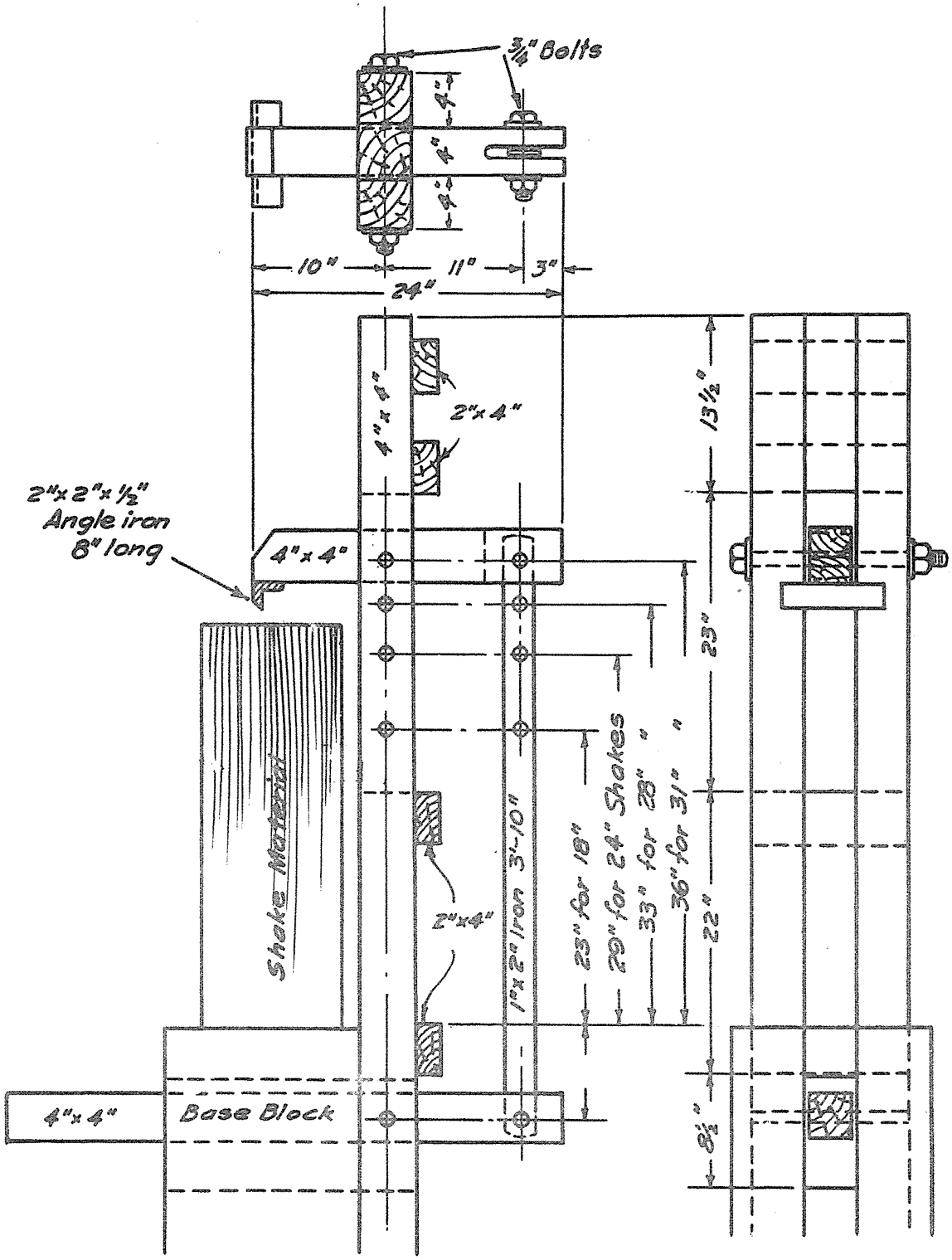


END VIEW



OUTSIDE WALL

SHAKE PRESS PLANS



SPLITTING TABLE AND SHAKE BOLT JACK

SHAKE MAKING EQUIPMENT

(e) Thickness Gauge.

The thickness gauge is used to insure a uniform thickness of the butts of the shakes. The gauge should be made of a good grade of steel. It can be manufactured at any mechanical shop from the drawing shown on page 308.

The gauge is used by placing it against the face edge of the bolt and placing the sharp edge of the gauge down to the end of the cut and tapping lightly with the mallet. This procedure gives the proper butt thickness for the shake and provides a groove into which the froe blade may be placed.

D. Splitting Shakes.

The following simple method of producing tapered shakes is given as information:

The bolts should be placed on the splitting table, locked into place with the jack and held rigidly by the pressure of the operator's foot on the jack lever. The butt thickness should be marked on the bolt as described in Article 186-E. The froe blade should be placed in the groove made by the gauge, and tapped lightly with the mallet to start the splitting. Care is necessary to avoid driving the froe too deep at the start. After the froe blade is started, the handle should be removed and the blade gradually forced down. This causes the shake to split away from the bolt and gradually become thinner as it approaches the bottom. The bolt should be turned end for end after each shake is split so that the proper taper may be secured.

The thickness of shakes will vary even with the use of the gauge. Gauges must be used while training inexperienced labor, but may be dispensed with when the operators become properly proficient.

E. Seasoning.

After shakes have been split they should be stacked for seasoning. They may be double-stacked using stickers, or end to end lap-stacked. The length of time required for seasoning is variable. It depends upon the weather, upon the species of wood, and upon whether live or dead timber was used for making the shakes. Green shakes of all species, except oak, will ordinarily air dry in one or two months in good seasoning weather. Oak shakes will probably require three months for proper seasoning.

(a) Stacking.

When shakes are double-stacked using stickers, they are placed cross-wise in the pile in double thicknesses on 3/4 inch stickers. A space of 2" or 3" should be left between the pieces in the layers. Piles are started on 2" x 4" stringers, laid on the ground and properly leveled. The shakes are then laid across the stringers. Piles should be about 4 or 5 feet high and one shake-length wide. They should be placed approximately one foot apart. Piles are made stable

by tying them together with stickers or shakes which extend from one pile to the other.

When shakes are stacked end to end, they are placed lengthwise in the pile and one end is lapped over the other. When shakes are stacked in this way the piles are started on 2" x 4" stringers laid on the ground with an additional piece laid across the stringers to receive the first layer. Piles should be about 4 or 5 feet high and about 3 average shake-widths wide. This will usually be between 18 inches and 24 inches. Piles should be placed approximately one foot apart and tied together as described above.

F. Bundling.

After shakes have been thoroughly seasoned, they should be packed in bundles. This will prevent damage or loss, will facilitate in estimating quantities and will save time and trouble in handling. If shakes are to be bundled without the use of a press, they should be placed in a single tier, one shake wide, and the bundle should contain 25 shakes. If a press is used, the bundle should be 20 inches wide and the standard number of layers in each bundle should be as follows:

31 inch shakes	7-7 pack
24 inch shakes	14-13 pack
18 inch shakes	18-18 pack

The figures in the right-hand column indicate the number of tiers of shakes in each end of the bundle, i.e., a 14-13 pack is made with 14 layers on one end and 13 layers on the other end.

The bundles should be securely bound by using 1/2" x 3" x 20" pieces of wood at the top and bottom. Strips of sheet metal 1" or 2" wide should be used at the sides and should be securely nailed to the wooden binding strip as removed from the press. Wires must not be used to fasten bundles.

After the shakes have been packed in bundles, they should be stored in a dry, well ventilated place until needed for construction work.

G. Quantities Needed.

The following tables give the estimated quantities of hand-split shakes laid shingle style, required to cover 100 square feet, using various amounts of weather exposure:

31" length

7 - 7 pack - Bundle 20" wide
Average width 8" - 35 shakes to bundle

Location	Weather Exposure inches	Shakes Required to Cover 100 sq. ft.	Bundles Required to Cover 100 sq. ft.
Roof	6	300.	8.57
"	6-1/2	276.9	7.91
"	7	257.	7.34
"	7-1/2	240.	6.85
"	8	225.	6.40
"	8-1/2	211.65	6.04
"	9	199.95	5.70
"	10	180.	5.14
Wall	10	180.	5.14
"	11	163.5	4.66
"	12	150.	4.28
"	13	138.45	3.95
"	14	128.55	3.67

24" length

14 - 13 Pack - Bundles 20" wide
Average width 8" - 67½ shakes to bundle

Location	Weather Exposure inches	Shakes Required to Cover 100 sq. ft.	Bundles Required to Cover 100 sq. ft.
Roof	5-1/2	327.15	4.84
"	6	300.	4.44
"	6-1/2	276.9	4.10
"	7	257.	3.82
Wall	7-1/2	240.	3.55
"	10	180.	2.66
"	10-1/2	171.3	2.53
"	14	128.55	1.90

18" length

18 - 18 Pack - Bundles 20" wide
Average width 8" - 90 shakes to bundle

Location	Weather Exposure inches	Shakes Required to Cover 100 sq. ft.	Bundles Required to Cover 100 sq. ft.
Roof	5-1/2	327.15	3.63
Wall	6	300.	3.33
"	6-1/2	276.9	3.07
"	7	257.	2.85
"	7-1/2	240.	2.66
"	8	225.	2.50

H. Use of Shakes.

(a) General.

The edges of shakes should not be trimmed except around openings or at valleys, hips and ridges, where a close fit is necessary. Shakes should not be placed too close together, but a space of from 1/8" to 1/4" should be provided between adjacent shakes to allow space for expansion during wet weather. Joints between shakes in adjacent courses should be broken with not less than a 2 inch side-lap.

(b) Under Courses.

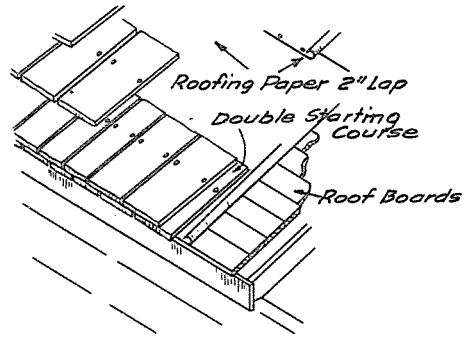
When an under course of shingles is used, the shakes should overlap the butts of the shingles on each course about 1/2 inch. This will provide a more pleasing appearance to the finished surface and will tend to prevent an accumulation of dirt at the lower end. Both courses should be carefully laid to avoid coinciding spaces.

(c) Nailing.

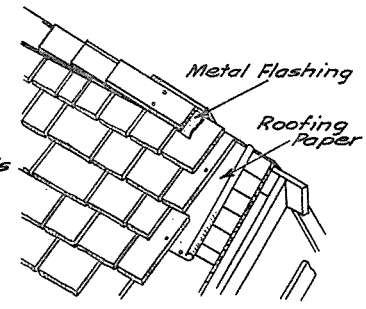
Shakes should be held in place with two nails placed approximately 1/2 inch from each edge and under the lap of the succeeding course. Nails should be driven just firmly enough to hold the shakes snugly against the sheathing. If nails are driven too hard, the structure of the shakes may be broken and splitting may result. Shakes should be nailed with wire nails which have been zinc-coated by the hot dipping process.

(d) Laying Shakes on Roofs.

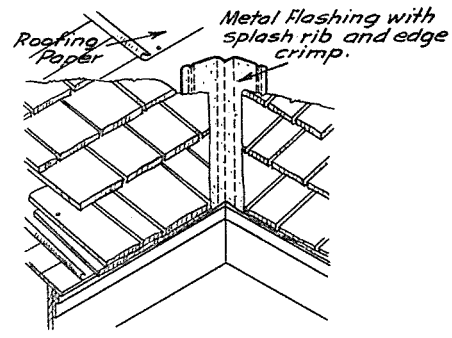
Shakes should be laid in straight courses over tight sheathing with the proper weather exposures shown above. Before the shakes are applied, the sheathing should be covered with a 30 lb. prepared roofing paper, laid with a 4-inch lap. The roofing paper protects the building before the shakes are laid. It also allows better drying of the shakes and provides protection against water leakage and air in-



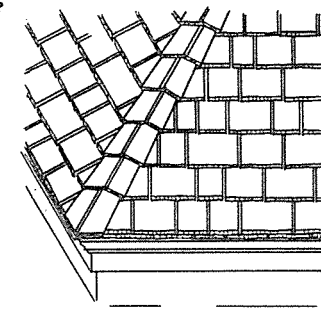
ROOF DETAIL



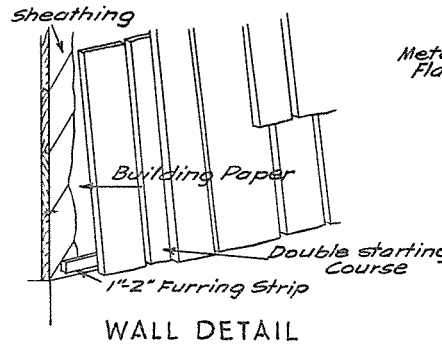
BOSTON RIDGE



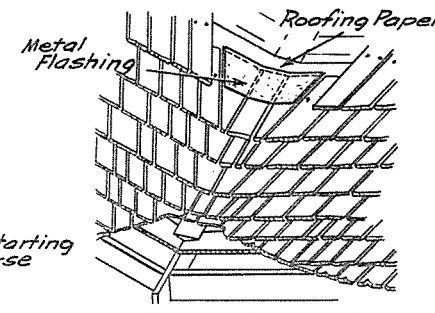
OPEN VALLEY



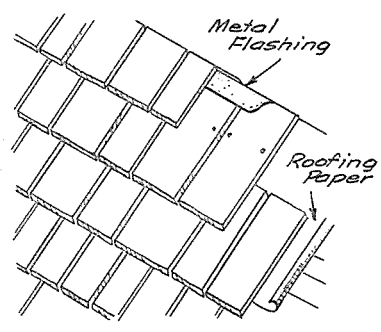
BOSTON HIP



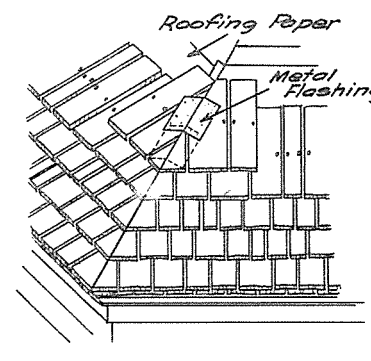
WALL DETAIL



CLOSED VALLEY



MITRED RIDGE



MITRED HIP

METHOD OF LAYING SHAKES

filtration. Proper methods of laying shakes are illustrated on Page 315.

The laying of shakes should start at the eaves with a double course. Each succeeding course should be laid at the proper exposure distance which has been marked by a chalk line. Each shake should be fastened by two nails, as illustrated in the upper left-hand diagram on Page 315.

Closed valleys should be rounded over a 1" x 6" saddle, which has been securely nailed in the valley. A sheet of metal flashing 2 inches longer than the shake exposure and sufficiently wide to extend 8 inches up on either side of the valley, should be placed between each course of shakes. All valley shakes should be fastened so that the nails will come under the lap of the metal flashing.

Open valleys should be formed with 20-inch metal flashing sheets having a 3-inch splash rib down the center and a 1/2 inch crimp on the outer edge. Shakes should be cut parallel to the valley to form an open valley not over 6 inches wide. Shakes should not be nailed through the flashing.

Mitred hips should be laid tight and should be flashed under each course with a sheet of metal flashing 8 inches wide and 2 inches longer than the shake exposure. Nails should not go through the flashing except at the outside corners.

Mitred ridges should be laid tight over a continuous strip of metal flashing 8 inches wide, which extends down 4 inches on each side of the ridge under the last course of shakes. The ridge shakes should be mitred and nailed close to the butts and toe-nailed at the mitred joints. Nails should not be allowed to go through the flashing.

Boston hips and ridges should be formed with shakes having a uniform width of 6 inches, laid in horizontal courses over a continuous strip of metal flashing 8 inches wide which extends 4 inches on each side of the hip or ridge. The exposure of shakes used on hips or ridges should be the same as for those used on the roof.

(e) Laying Shakes on Walls.

Shakes should be laid in straight courses over tight sheathing and heavy water-proof building paper with the proper weather exposure as shown above.

Shakes should be started at the water table. A 1" x 2" furring strip should first be nailed to the side wall 1 inch above the water table. On this is laid a double course of shakes. The starting course should be butt nailed to the furring strip. The outer course should be nailed in the usual manner with the proper weather exposure which has been marked by a chalk line.

187. Roofing Felt.

Roof surfaces on which metal, slate, tile or wood shingles are to be placed, should be covered with asphalt roofing felt. Roofing felt which weighs approximately 30 lbs. per square must comply with Federal Specification HH-F-191, Type 2.

The felt should be laid horizontally. Vertical and horizontal joints should be lapped 4 inches and should be cemented together. The felt should be lapped at least 4 inches over all valley and gutter metal and should extend 12 inches over hips and ridges. It should be turned up 6 inches against all abutting vertical surfaces. Felt should be fastened with large headed copper roofing nails, spaced not over 6 inches apart. It should be protected against damage before the flashing and roofing is applied.

188. Mineral Surfaced Rolled Roofing.

This type of roofing is not desirable for high-class permanent structures, but may be used for temporary buildings. It must comply with Federal Specification SS-R-511. The material should be laid in strict accordance with the manufacturer's printed instructions which come with each roll.

189. Slate.

If slate is used as a roofing material it should conform to the grading standards of the National Slate Association. Each piece must be 20 inches long, but may be of random widths.

The slate should be hard, dense, and sound. It must be punched for two nails for each piece. A limited amount of hand-punching may be permitted while the slate is being laid.

Slates should be laid in horizontal courses with a 3 inch head lap. Each course should break joints with the preceding one. If random widths are used, the overlapping slate should be jointed as near to the center of the under slate as possible, and not less than 3 inches from any under-jointing. Slate should be placed with two thicknesses at the eaves, the same as wood shingles.

Slate which overlaps sheet metal work should have the nails so placed as to avoid puncturing the metal. Exposed nails should be permitted only in the top courses. The slate at hips should be so cut that the bond will be uniform with the bond at other places. It should be neatly and closely fitted, without metal underflashing. Butt joints at hips should be bedded in and pointed with an elastic cement.

Slate should be fastened to wood sheathing with copper or hot galvanized nails. The nail head should be covered with an approved brand of waterproof elastic slater's cement.

190. Curved Tile Roofing.

The most commonly used material of this kind is the S-type, curved Spanish Roofing Tile. They are usually about 10-1/2 inches wide, 13-1/4 inches long and 1/2 inch thick. They should be manufactured from the best quality of shales and clays. They should be hard-burned, waterproof, fireproof, and stainproof, and manufactured by modern methods in a full range of variegated reddish colors. Suitable matching ridge and hip cover tiles and valley tiles should be furnished.

Before the tiles are laid, the sheathing should be covered with a layer of 30 lb. asphalt roofing felt. All necessary wood strips should be provided and all flashing should be in place before tile laying is started.

Tile should be laid with regular butt lines and should have an average exposure of 8-1/4 inches. The tile should be fastened in place with copper or hot dipped galvanized nails, except where it overlaps metal flashings. At these points, the tile should be fastened with copper wires and with elastic cement. Waterproofing is provided at hips by the use of elastic cement and at gables by the use of a mortar of the same proportions as is used for laying brick.

191. Flat Tile Roofing.

The materials used for flat roofing tiles are exactly the same as those used for curved roofing tiles. The method of manufacture is the same except for the size and shape of the tile. Flat tiles are usually 7 inches wide, 15 inches long and 1/2 inch thick. The method of laying is the same as that described for curved tile, except that flat tile has an exposure of only 6-1/2 inches instead of 8-1/4 inches.

192. Metal Roofing.

The use of metal will seldom be necessary for covering Forest Service buildings. If its use should be necessary the sheets should be laid singly with staggered flat seams and should be secured by cleats. Sheets of metal roofing are usually 16" x 24" and are of #22 to #28 gauge material.

193. Slag or Gravel Roofing.

Slag or gravel roofing is sometimes used to cover Forest Service buildings if the roof slope is not too steep. This type of roof covering is built up in layers. The usual method of covering wooden sheathing is as follows:

First, a layer of untreated roofing paper or felt is placed over the sheathing and securely fastened with nails.

Second, The roofing paper should be covered with a thin coat of asphalt. Three, four or five layers of 30 lb. treated roofing felt should be placed over the

building paper. As each layer is placed, it should be mopped with a coating of asphalt or tar and should overlap the previous layer in a manner similar to the lapping of shingles.

Third, After the final layer of felt has been placed, the entire roof surface should be covered with a uniform coating of pitch or asphalt to which slag or gravel has been added.

About 4 lbs. of gravel or 3 lbs. of slag will be needed to cover one square foot of roof surface. The total weight per square foot of slag or gravel roofing is usually between 6 and 7 lbs.

Standard specifications for this type of roofing may be obtained from any manufacturer of prepared roofing material. The specifications used by the various manufacturers are the same with the exception of the manufacturer's name and the trade name of the materials specified.

These specifications not only give the make-up of each material, but lay down special rules for the application of them.

CHAPTER XX - LATHS, PLASTER AND STUCCO

194. Wood Lath.

Laths which meet the specifications given in Chapter X, include white pine, fir, spruce and hemlock. Woods which are heavy in pitch are not good materials for laths. Laths should be well-seasoned and free from bark and dead knots. Bark on laths will cause stains in the plaster and provide an unsightly appearance. The standard size of laths is 3/8" x 1-1/2" x 48", but the width and thickness varies somewhat in different mills. Laths are put up in bundles of 100.

Wood lath should be spaced not less than 3/8 inch apart to provide a good key for the plaster. The ends of the laths should not be butted tightly together and all joints should be broken every 15 inches. Laths should extend down to the floor and should be run horizontally instead of vertically or diagonally. They should be securely fastened by 3d lathing nails at each joint and at each intermediate stud.

Laths should be thoroughly soaked before plastering is applied. This operation permits swelling of the laths and aids in preventing cracked and bulged plaster.

195. Metal and Wire Lath.

A. Metal Lath.

Metal lath is made from specially processed steel sheets slit or punched and then expanded or otherwise formed into a network or web of steel. It contains numerous openings to facilitate the spreading of the plaster and its keying to the steel. Each sheet of metal lath is covered with a special preservative paint or is cut from galvanized sheets. After the lath is in position in the building the plaster which is applied over it affords permanent protection to the steel.

Expanded metal lath is furnished in standard lengths of 8 feet and in widths of from 14 to 24 inches. The material should not be lighter than #27 U.S. Gauge. Unless otherwise specified flat expanded painted metal lath should not be lighter than 3.4 lbs. per square yard and must comply with Federal Specification QQ-B-101a, Class E.F.R. If copper bearing base metal is required it should be specified on the drawings.

Metal lath should be applied with the long dimension of the sheet across the supports. Lath should be lapped not less than 1/2" at the sides and not less than 1" at the ends. End laps of sheets should generally occur only over supports. If the lapping falls between supports the ends of the sheets should be securely laced to-

gether with #18 galvanized annealed wire. Sheets should be secured by hot dipped galvanized nails, or #18 gauge galvanized annealed wire ties, at intervals not exceeding 7 inches. Ties, nails, or other attachments should always be placed where the sides of the sheets lap at supports. Ties of side laps should be made at intervals not exceeding 9 inches.

Metal lath should be first applied to the ceilings and the sheets should be carried down 6 inches on the walls and partitions. If metal lath is not used on the ceilings, the lathing should start at the top of the wall and be bent and carried up 6 inches on to the ceiling joists. On walls, the lath should be started one stud-distance away from the corner and should be bent into the corner and be carried on to the abutting wall. Laths should be placed so that the lower sheet laps over the upper sheet. Various metal lath applications are illustrated on Pages 323 and 324.

B. Wire Lath.

Woven wire lath is often used instead of expanded metal lath because of the difference in cost. It is usually lighter than expanded metal lath and will give sufficiently good results when used in partition walls. Woven wire lath comes in any number of widths up to 10 feet and is usually obtainable in rolls of 100 to 200 feet. It should not be lighter than #20 U. S. gauge and should be galvanized by the hot dipping process after it is woven.

Wire lath should be stretched tightly as it is placed. The end joints of sheets should be made only at bearings and should be staggered. Woven wire lath should be fastened to the supports in the same manner as expanded metal lath.

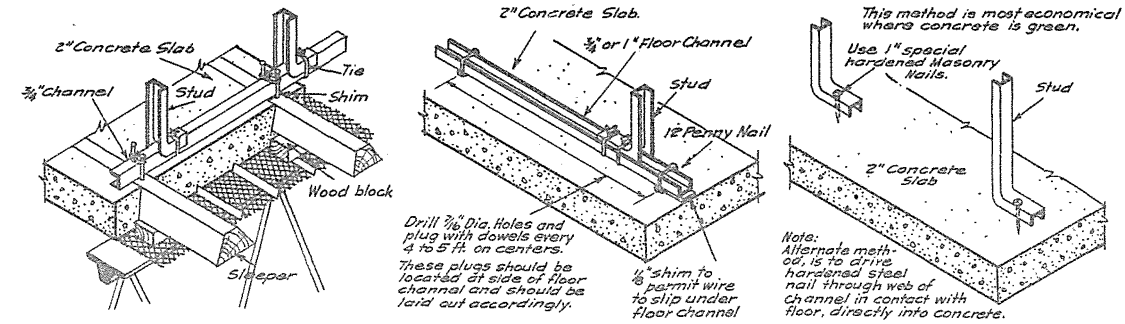
196. Furring and Grounds.

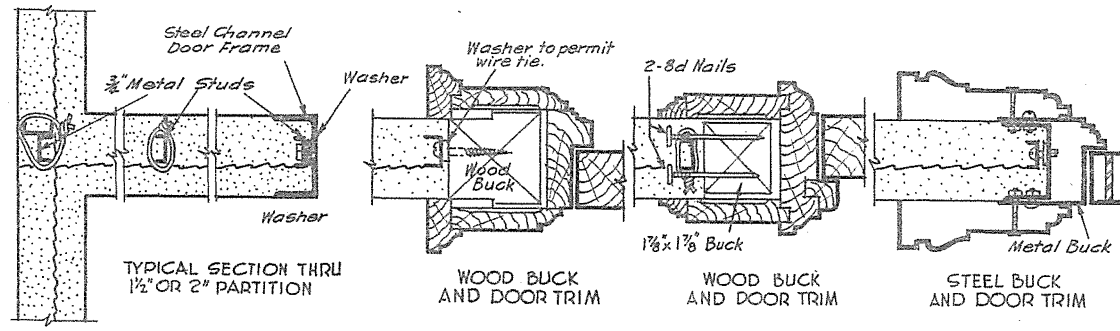
A. Furring.

(a) Wood Furring.

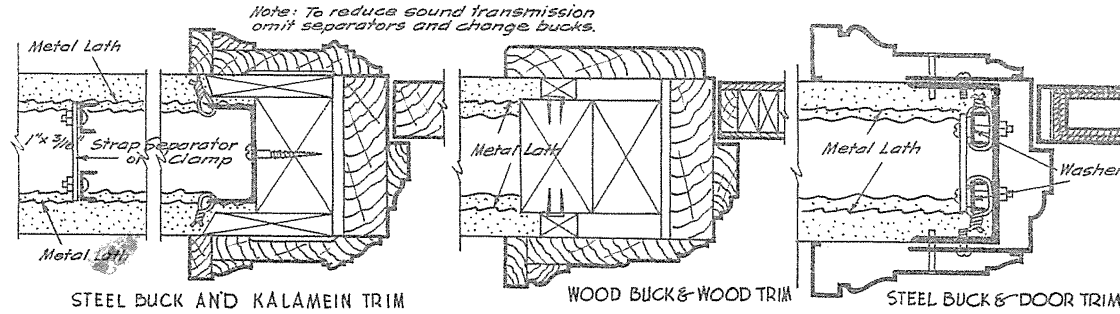
Wood furring strips are used in conjunction with wooden laths if the laths are not nailed directly to the studding. Furring strips are, as the name implies, strips of wood about 7/8" x 2". They are nailed in a vertical position, directly to the sheathing and spaced either 12 inches or 16 inches on centers. The laths are attached to the furring strips, thus separating the 7/8" from the sheathing and allowing sufficient room for the plaster keys.

Furring strips may be securely fastened to brick walls by nails driven into the mortar joints. They may be fastened to concrete walls by the use of case hardened nails which can be driven directly into the concrete. If it is impossible to drive nails into the concrete, holes should be bored and metal nailing sleeves inserted.

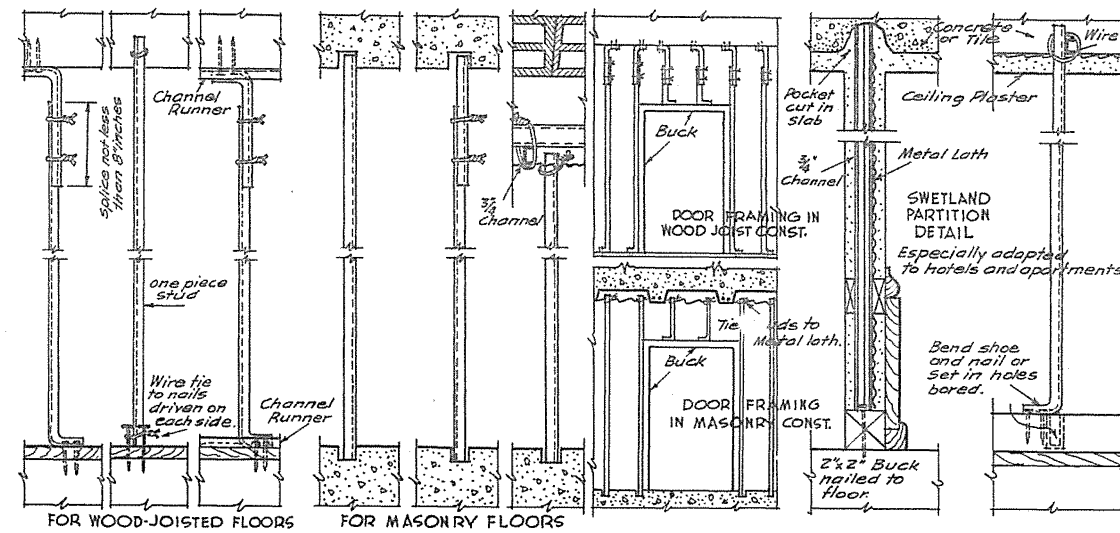

2" Concrete Slab
Tie
3/4" Channel
Stud
Shim
Wood block
Sleeper
2" Concrete Slab.
3/4" or 1" Floor Channel
Stud
12 Penny Nail
Drill 7/16" Dia. Holes and plug with dowels every 4 to 5 ft. on centers.
These plugs should be located at side of floor channel and should be laid out accordingly.
1/8" shim to permit wire to slip under floor channel
This method is most economical where concrete is green.
Use 1" special hardened Masonry Nails.
Stud
2" Concrete Slab
Note: Alternate method, is to drive hardened steel nail through web of Channel in contact with floor, directly into concrete.



DETAILS SHOWING METAL LATH AND STUDS IN 2" SOLID PARTITIONS


Note: To reduce sound transmission omit separators and change bucks.
Metal Lath
1" x 3/16" Strap Separator or Clamp
Metal Lath
STEEL BUCK AND KALAMEIN TRIM
Metal Lath
WOOD BUCK & WOOD TRIM
Metal Lath
Washers
STEEL BUCK & DOOR TRIM

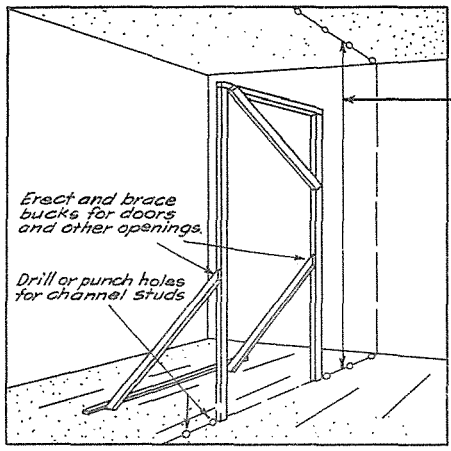
DETAILS SHOWING METAL LATH AND STUDS IN 4" HOLLOW PARTITIONS



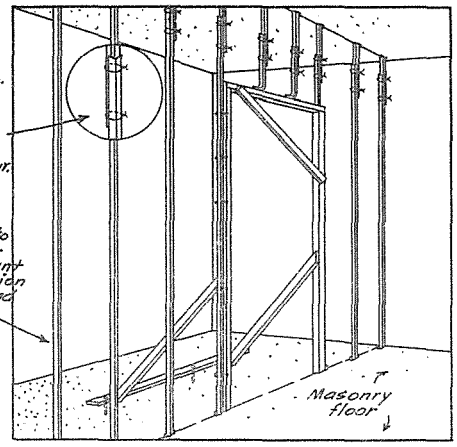
ANCHORAGE METHODS OF STUDS

COURTESY OF METAL LATH MANUFACTURERS ASSOCIATION

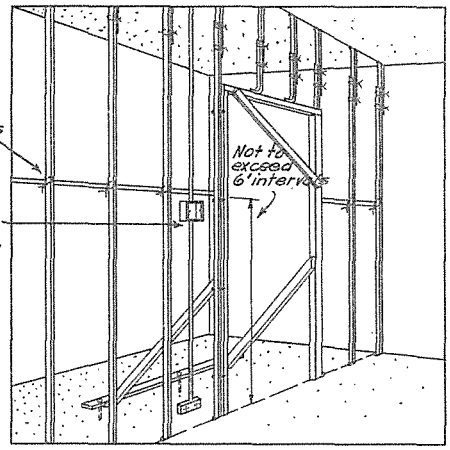
METAL LATH DETAILS


Lay out location of partition with chalk line and find average height between floor and ceiling.
Erect and brace bucks for doors and other openings.
Drill or punch holes for channel studs

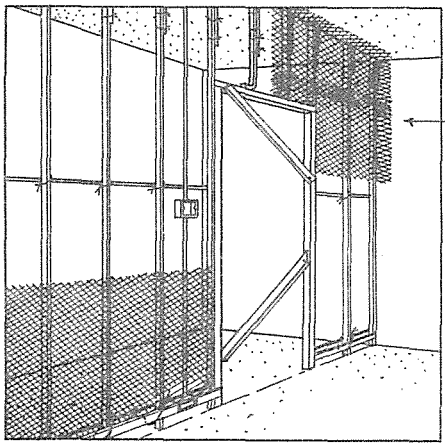
LOCATION LAYOUT, ERECTION AND PLUMBING OF BUCKS AND ANCHORAGE FOR STUDS.


Allow 8" Lap wherever splices occur.
Cut studs to length allowing for amount of penetration into floor and ceiling.
Masonry floor

ERECTION OF STUDS SHOWING SPLICING OF TWO-PIECE STUDS


Erect temporary braces for studs
Not to exceed 6' intervals
Install electrical conduit and outlets using shallow switch boxes, etc.

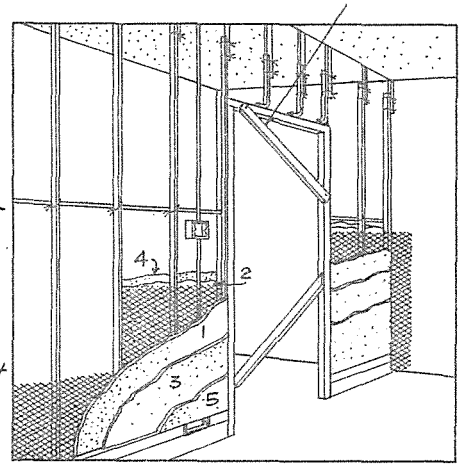
TEMPORARY BRACING OF STUDS, INSTALLATION OF ELECTRICAL CONDUITS.


Lath started at ceiling lapping 4" on ceiling and adjoining walls.
Apply metal lath, grounds, and complete electrical Construction.

ORDER OF APPLICATION

1. Scratch coat lath side.
2. Backing up coat channel side.
3. Brown coat lath side.
4. Finish coat channel side.
5. Finish coat lath side.

APPLICATION OF METAL LATH, LAPPING ON CEILING AND ABUTTING WALLS, APPLICATION OF GROUNDS AND SCREEDS.



STEPS IN APPLICATION OF PLASTER

COURTESY OF METAL LATH MANUFACTURERS ASSOCIATION

USE OF METAL LATH IN PARTITIONS

(b) Metal Furring.

Metal furring channels should be used when the use of metal lath is specified. Channels should be galvanized or painted as a protection against oxidation. They are placed vertically with a spacing of from 12" to 19" depending upon the stiffness of the lath.

If horizontal furring is required, the channels should be not less than 3/4" and the spacing should not exceed 4'6". Horizontal furring may be omitted where furring devices or clips are either poured in place in the concrete, or may be secured to masonry.

Metal furring channels are usually made of #16 gauge cold rolled steel. The flanges are 3/8" wide with the channels themselves having the following widths and weights for each 1,000 linear feet:

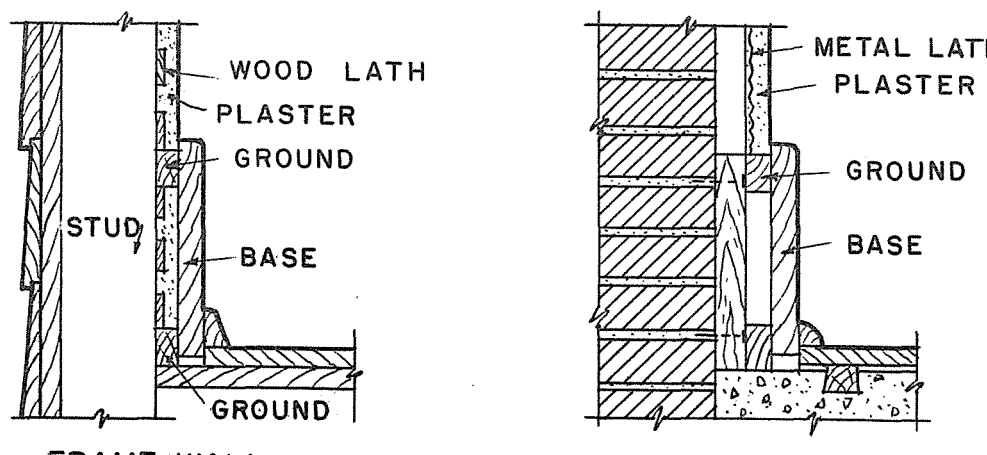
Size, inches	Weight, lbs.	Size, inches	Weight, lbs.
3/4	276	1-1/2	442
1	332	2	553

If the channels are hot rolled, the shapes should not be less than 1/8" thick.

Metal furring should include all bolts, inserts, clips, fasteners and hangers. The attachments should be of the proper size and design. A sufficient number should be used so that the full strength of the members may be developed.

B. Grounds.

Grounds are strips of wood which have been surfaced to a uniform thickness. They serve as guides for bringing the plaster to an even surface. They are placed around all openings and along the bottom of walls near the floor and serve as nailing strips to which baseboards and inside finishes are nailed. They should be set flush with the face of the final coat of plaster. Illustrations of base grounds for both frame and brick walls are shown below:



FRAME WALL BRICK WALL

BASE GROUNDS

197. Metal Corner Beads and Joint Strips.

A. Corner Beads.

Corner beads are used both for corner protection and as plastering grounds. Many types are available and all can be attached readily to metal lath. Beads should be used on all vertical and horizontal external plaster corners which will not be covered by other finishes.

Metal corner beads should be #26 gauge galvanized sheet metal with perforated or expanded flanges not less than 3-1/2" wide. They should have braces or stays so shaped that a good bond may be secured with the plaster to form a substantial rigid corner.

B. Joint Strips.

An 8" strip of #24 gauge metal lath should be applied for the full length of the joint at the junction of wood lath and masonry or at other places where it is necessary to cover joints between different materials. Joint strips may also be used to reinforce all internal plaster corners.

198. Composition Wall Boards.

Composition wall boards used as a base for plaster must comply with Federal Specification UU-W-101. Gypsum plaster boards must comply with Federal Specification SS-P-431. The required sizes of boards should be specified on the drawings.

199. Plaster.

Plaster is a mixture of sand, or other fine aggregate with a binder of lime, gypsum or cement and hair or fiber. A sufficient amount of water is added to form a mortar that is plastic and easily handled.

Plaster may be applied directly to the surface of brick, hollow tile or concrete walls. This method of construction is discouraged because of the possibility of discoloration of plaster by the penetration of moisture from the walls. Furring strips should be used as described in Article 196.

Three coats of plaster should be applied over laths. If laths are not used as a base, two coats will be sufficient. Various kinds of plaster may be used and will be briefly described later on in this article.

With the exceptions of the finish coat, the plaster should be carried to the floor behind baseboards, wainscoting, etc., but may be omitted behind marble finish. All exterior windows and doors should be temporarily covered during the plastering operation and until the plaster has become dry.

A. Materials.

(a) Sand.

Sand used for making mortar should have clean, hard, particles, well-graded in size. All sand should pass a #8 standard sieve, but not more than 80% should pass a #30 sieve nor more than 20% should pass a #50 sieve. The sand must not contain more than 5% of silt or other foreign matter.

(b) Water.

Water should be clean and free from strong acids, alkalis, oil and organic materials.

(c) Lime.

Lime may be either hydrated or lump. Hydrated lime is in powder form and is prepared by slaking lump lime at the place of manufacture. Hydrated lime must conform to Federal Specification SS-L-351, Type F for plaster.

If lump lime is used in making plaster, it must first be slaked with water. Slaking produces extreme heat and the mixture must be allowed to set and cool for several days before using.

(d) Gypsum.

Gypsum or plaster of Paris is made from gypsum rock that has been heated until approximately 3/4 of the water of crystallization has been driven out. Plaster made from gypsum must comply with Federal Specification SS-P-401, Type W.

(e) Cement.

Portland cement used for making plaster should be of an approved standard brand and must comply with Federal Specification SS-C-191a, and the rules of the Portland Cement Association.

(f) Hair.

Hair which is used by plasterers is obtained from the hides of cattle. It should be thoroughly washed and dried before being used. Hair should never be added to a lime mixture while the lime is hot.

(g) Fiber.

Asbestos fiber or manila fiber is often used as a substitute for hair. It is much cleaner and is less likely to be damaged by the lime.

B. Mixing.

Plaster should be mixed in the following proportions for scratch coats and brown coats. The white finish coat for interior use is made of the combination of lime putty and gypsum, mixed in the proper proportions. The proportions used are left largely to the discretion of the plasterer, who must gauge the time of set by the area to be covered and by the weather. The usual proportions are 200 lbs. of finishing hydrated lime to 50 lbs. of plaster of Paris or gypsum.

(a) Lime Putty.

(1) Scratch Coat:

4/5 part stiff lime putty
1/5 part plaster of Paris
3 parts dry plastering sand
6 lbs. of hair for each cu. ft. of mortar

(2) Brown Coat:

9/10 part stiff lime putty
1/10 part plaster of Paris
4 parts dry plastering sand
3 lbs. hair per cu. ft. of mortar

(b) Gypsum Plaster.

(1) Scratch Coat:

By volume:

1 part gypsum
1-1/4 parts sand

By Weight:

100 lbs. gypsum
175 lbs. sand

3 bu. hair per cu. yd. of sand

(2) Brown Coat:

By volume:

1 part gypsum
2-1/2 parts sand

By weight:

100 lbs. gypsum
350 lbs. sand

1/2 bu. fiber per cu. yd. of sand

(c) Portland Cement Plaster.

(1) Scratch coat:

1 part Portland cement
3 parts sand
3 bu. hair or fiber per cu. yd. of sand
10% hydrated lime by weight of cement

(2) Brown coat:

1 part Portland cement
3 parts sand
1-1/2 bu. fiber per cu. yd. of sand
10% hydrated lime by weight of cement

(d) Keene's cement plaster.

(1) Scratch coat:

10 cu. ft. stiff aged lime putty
200 lbs. Keene's cement
1 lb. hair or fiber
1 cu. yd. sand

(2) Brown coat:

7 cu. ft. stiff aged lime putty
150 lbs. Keene's cement
1 cu. yd. sand

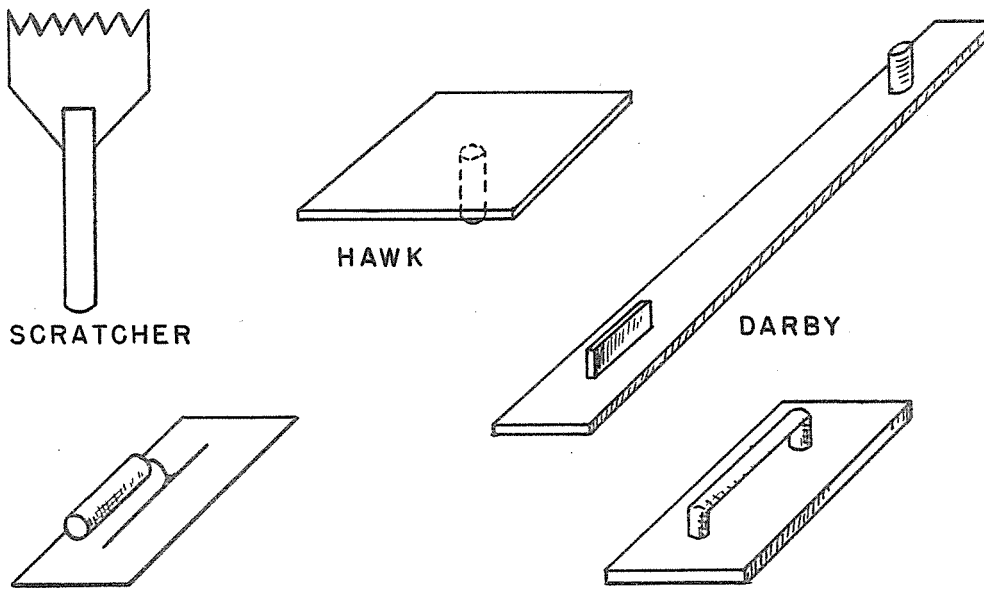
Note: Keene's cement is a calcined gypsum prepared under a special formula by various manufacturers. It will give a very hard smooth surface when it is properly applied. It is used where a hard sanitary surface is required and is usually finished to imitate wall tile. It is especially adaptable for use in bathrooms, toilets, and washrooms.

C. Application.

Plaster is usually applied in three coats. The scratch coat is the first coat and is placed as a foundation for subsequent coats. It is usually not more than 1/4" thick and should be applied as thinly as possible. It keys the entire plaster surface to the laths.

The second, or brown coat, should be applied to the scratch coat after it has dried sufficiently to provide a holding base. An exception to the above is that when red cedar laths are used, the scratch coat must be thoroughly dry before the brown coat is applied. The brown coat should be built up to within 1/8 inch of the final finished surface.

The finish coat is usually 1/8" thick and is not applied until after the brown coat is thoroughly dry. It should be applied true to the ground and guide lines and should be smoothed with a trowel to a satisfactory surface. The finish coat should show no visible joints, cracks, or discolorations.



PLASTERER'S TOOLS

200. Stucco.

Stucco consists of a plaster made of Portland cement or gypsum combined with sand, fine gravel or stone chips and applied to the outside surface of walls. Its composition is, in many ways, similar to that of plaster with the exception of the larger grained aggregates. It is usually applied in three coats.

Stucco may be applied directly to the surface of hollow building tile, brick, or concrete, but good practice suggests the use of metal lath attached to furring strips. The final thickness of stucco should be at least 7/8", and should be thoroughly keyed to the wall, so that it will not drop off because of its own weight.

Stucco should not be applied when the temperature is below 45° F, unless the wall has been suitably protected against freezing. During hot, dry weather, stucco should be suitably protected to prevent too rapid drying.

CHAPTER XXI - HEATING

201. General.

It will usually be the best practice to engage a competent heating contractor to supervise the installation of the equipment for assurance as to the efficiency of the heating plant. Forest Service heating and ventilating plants will generally be designated in the building or structure plans. The smaller buildings may be heated with stoves. In some cases, small offices and dwellings up to four rooms will be heated with pipeless air furnaces. Larger buildings may have gravity or forced air heating systems or they may be heated by steam or hot water. Heating equipment may be planned and installed for the use of wood, coal, oil or gas. Any of these means of heating will be adequate if the design and installation are correct.

202. Calculation of Heat Losses.

The following methods of heat calculation will prove satisfactory. In making computations, there are many factors which are peculiar to each job. These may be insulation, temperature or exposure to sun and wind. These methods of computation should serve only as a means of making general estimates. Planning of heating plants should be left to the engineering divisions of the Regional Offices.

Heat flows from substances of high temperature to substances of low temperature. To maintain the warmth of a room when the adjacent temperatures are lower, an amount of heat equal to that which is constantly flowing away must be added to the air in the room. This may be expressed thus:

Heat to be Supplied = Heat Losses

Calculation for a heating installation is divided into two parts: The heat loss must first be determined; the conditions required to balance that loss must then be calculated.

Quantities of heat are measured in British Thermal Units called "Btu". A Btu is the amount of heat required to raise the temperature of one pound of water 1° F. Heating calculations are made on the basis of one hour as the unit of time.

Heat is lost from a room in three ways:

Through glass,
Through outside walls, floors and ceilings,
and through walls, floors and ceilings adjacent to unheated spaces,
By infiltration.

The formula may then be expressed:

Heat to be Supplied = $HL_G + HL_W + HL_I$

To make heat loss calculations it is necessary to arrive at the temperature at which the room is to be maintained. This is known as the "inside temperature" and is indicated as t_i.

VALUES USUALLY SPECIFIED

Room	t_i
Toilets and Baths	70° F.
Kitchens	66° F.
Dining and Lunch Rooms	65° to 70° F.
Bedrooms and Baths	70° F.
Living Rooms	70° to 72° F.
Public Buildings	68° to 72° F.
Storerooms and Shops	60° to 65° F.
Paint Shops	80° F.
Garages	60° to 70° F.

It is usually necessary to determine the "outside temperature" indicated as t_o. A temperature of 15° above the lowest on record is usually assumed, since extremely low temperatures are usually of short duration and are rarely repeated in successive years.

A. Heat Loss through Glass = HL_G.

The amount of heat in Btu's which is lost per square foot per hour per degree differences in temperature is called the coefficient of heat transmission. Those coefficients which apply to glass and glazing are indicated by the symbol k_G. It should be obvious from the definition that the total heat loss through a window or skylight would be its area in square feet (A_G) times the coefficient (k_G) times the difference in temperature ($t_i - t_o$). This may be expressed as follows:

Total Heat Loss through Glass = $A_G\ k_G\ (t_i - t_o)$

The areas of windows, skylights and other glazed areas are calculated from the architectural drawings. Doors with thin panels of veneer wood or similar material are calculated as glass areas.

Assume that a room contains two windows measuring 3 feet by 5 feet. The total area is 30 square feet. The coefficient for a single glazed window is 1.13. With a difference in temperature of 70° F, the calculation would be thus:

Heat Loss through Windows = 30 x 1.13 x 70 = 2373 Btu's

The loss thus obtained is considered the heat loss through glass, designated by the symbol, HL_G.

FULL AREA OF TWO-PANE WINDOWS

Giving the total area of two-pane windows, including the sash

Width Glass	Width of Opening	Height Glass 18" / Height of Opening 3'-6"	24" / 4'-6"	30" / 5'-6"	36" / 6'-6"	42" / 7'-6"	48" / 8'-6"
24"	2'-4"	8.2	10.5	12.8	15.1	17.4	19.8
26"	2'-6"	8.7	11.2	13.7	16.2	18.7	21.2
28"	2'-8"	9.3	12.0	14.7	17.3	20.0	22.6
30"	2'-10"	10.0	12.8	15.6	18.4	21.2	24.0
32"	3'-0"	10.5	13.5	16.5	19.5	22.5	25.5
34"	3'-2"	11.0	14.3	17.4	20.6	23.7	27.0
36"	3'-4"	11.7	15.0	18.3	21.6	25.0	28.3
38"	3'-6"	12.2	15.8	19.2	22.7	26.2	29.8
40"	3'-8"	12.8	16.5	20.1	23.8	27.4	31.2
42"	3'-10"	13.4	17.3	21.0	24.9	28.6	32.6
44"	4'-0"	14.0	18.0	22.0	26.0	30.0	34.0
46"	4'-2"	14.6	18.8	23.0	27.1	31.2	35.5
48"	4'-4"	15.2	19.5	23.8	28.1	32.4	36.8
50"	4'-6"	15.7	20.3	24.8	29.2	33.7	38.2
52"	4'-8"	16.3	21.0	25.6	30.3	35.0	39.6
54"	4'-10"	16.9	21.8	26.6	31.4	36.2	41.0
56"	5'-0"	17.5	22.5	27.5	32.5	37.5	42.5

B. Heat Loss through Walls = HL_W

As stated before, the amount of heat in Btu's which is lost per square foot per hour per degree differences in temperature is called the coefficient of heat transmission. The coefficients which apply to walls, floors and ceilings are indicated by the symbol, k_W. It should be obvious from the definition that the total heat loss through outside walls, floors and ceilings or through walls, doors and ceilings adjacent to unheated spaces would be the area of the wall in square feet (A_W) times the coefficient (k_W) times the difference in temperature ($t_i - t_o$). This may be expressed as follows:

Total Heat Loss through Walls = $A_W k_W (t_i - t_o)$

The areas of walls, floors and ceilings are calculated from the architectural drawings. The coefficients of heat loss (k_W) through walls of various types are shown on Page 334.

The temperature of unheated spaces in a building is usually taken as the mean between the room and the outside design temperature. For instance, if the outside design temperature has been taken as 0° F., and the temperature of the room has been taken as 70° F., the temperature of unheated spaces in the building would be assumed as 35° F. It is possible that a basement room might have a part of its outside wall below grade and a part above grade. In such a case the "t_o" of the ground is taken as 50° F.

Kind of Wall	Value of k_W
2x4 stud wall, plastered	0.25
2x4 " " " , wall thick bat insulation	0.061
2x4 " " " 1/2" blanket insulation	0.16
2x4 " " " wallboard interior	0.19
4" Brick Veneer, 2x4 stud wall, plastered	0.27
4" " " 2x4 " " " , wall thick bat insulation	0.062
4" Brick Veneer, 2x4 stud wall, plastered, 1/2" blanket insulation	0.17
4" Brick Veneer, 2x4 stud wall, wallboard interior	0.21
Interior walls, plastered one side	0.62
" " " two sides	0.34
Floor, no ceiling below, sub-floor only	0.46
Floor, plaster ceiling below, sub-floor only	0.28
Floor, " " " , sub-floor and finished floor	0.24
Floor, plaster ceiling below, sub-floor and finished, 3-5/8" bat insulation	0.060
Floor, plaster ceiling below, sub-floor only, 3-5/8" bat insulation	0.063
Floor, plaster ceiling below, sub-floor only, 1/2" blanket insulation	0.16
Ceiling, plastered, no floor above	0.62
" " " " " 1/2" blanket insulation	0.24
Ceiling, plastered, " " " 3-5/8" bat insulation	0.067

If an attic or an excavated basement has open vents, the design temperature must be considered as the outside temperature. Excavated basements are not considered in heat loss loads unless they are used for recreation rooms, etc. and will need special heating. Their temperature is generally considered as 70° F. because of the heat thrown off from the furnace.

Assume that the total area of a wall exposed to the outside is 96 square feet. From this we subtract the area of the windows, 30 square feet, giving an actual wall area of 66 square feet. The coefficient is assumed to be 0.25 and the difference in temperature is assumed to be 70° F. The calculation would then be:

Heat Loss through Walls = 66 x 0.25 x 70 = 1155 Btu's.

A similar room may have a wall which is exposed to the outside, a portion of the roof similarly exposed, and the floor, ceiling, or inside partitions exposed to adjacent unheated spaces. A separate calculation is necessary for each condition. The sum of the losses thus obtained is considered the heat loss through walls, designated by the symbol, HL_W.

C. Heat Loss by Infiltration = HL_I

Cold air from the outside enters a building through cracks in the construction or through the walls themselves. Some engineers calculate the exact length of all cracks around windows, doors, etc., and arrive at a theoretical volume of air admitted. For most cases, however, it has become a general practice to assume a certain number of complete changes of air in a room per hour. The complete number of air changes used in heating calculations is indicated as "n" and is given in the following table:

NUMBER OF AIR CHANGES

Room	No.
Rooms, no windows or outside doors	1/2
Rooms, exposure 1 side	1
Rooms, exposure 2 sides	1-1/2
Rooms, exposure 3 sides	2
Rooms, exposure 4 sides	2
Living Rooms in Residences	1 to 2
Stairways and Inside Halls	1/2 to 1
Bedrooms	1-1/2
General Offices	3
Private Offices	4
Entrance Halls	2 to 3
Bathrooms	2

Whether or not the actual infiltration of air amounts to the number of air changes shown in the table, it has been found that the heating system should allow for the number given. Doors and windows are opened for ventilation purposes, thus changing the air in the room even though there is actually a very small infiltration. In rooms having forced systems of ventilation, part of the heat loss may be supplied by the warmed air and part by the radiation in the room.

The cubic contents of the room (C) times the number of air changes per hour (n) will give the volume of air which must be heated. It requires .018 Btu's to raise the temperature of 1 square foot of air 1° F. Therefore, if we multiply the total volume of air by .018, we will have the number of Btu's required to raise the temperature of the air 1° F. If this quantity is then multiplied by the number of degrees it is necessary to raise the temperature, we will have the total heat required to balance the infiltration loss. This may be expressed as follows:

Total Heat Loss by Infiltration = $.018\ n\ C\ (t_i - t_o)$

Assume a room having a floor area of 10 feet by 12 feet and a ceiling height of 9 feet. The cubic contents will be 1080 cubic feet. If two air changes per hour are desirable, and the difference in temperature is 70° F., the calculation then becomes:

Heat Loss by Infiltration = .018 x 2 x 1080 x 70 = 2722 Btu's.

The loss thus obtained is considered the heat loss by infiltration, designated by the symbol, HL_I.

203. Heating Systems.

A. Warm Air Heating Systems.

Most warm air furnaces are now designed and manufactured according to a "standard code" approved by the National Warm Air Heating Association. The gravity furnaces operate on the simple principle that warm air, being lighter than cold air, will rise and flow from the furnace through sheet metal ducts and registers to the various rooms.

Gravity warm air systems are very effective and cheap for small dwellings and offices. The maximum size of a structure which may be heated is 40 feet by 40 feet and three stories high. The system is limited by the requirement of a centrally located furnace. Leader lengths must pitch 1 inch per foot to the furnace and should not be over 10 to 12 feet long.

All heating pipes and registers must be kept away from outside walls and openings. Stacks must be run in interior partitions. Leaders must not be less than 8 inches in diameter. Recirculation ducts should be placed over windows, near doors or near sources of cold air. They should pitch 1/2" per foot in horizontal runs. Outside air ducts for cold air are not advisable in colder climates. Sharp curves should be avoided in all pipe installations.

Some warm air furnaces are equipped to force air from the furnace to the rooms. Forced air systems are more flexible than gravity systems because they permit a smaller size and a longer run of leader pipes.

B. Hot Water Heating Systems.

Hot water systems heat a house by the circulation of hot water through radiators. As with the warm air system, the principle of circulation is gravity. Hot water rises through the radiators, loses part of its heat by radiation and returns to the boiler in a cool state to be reheated.

Hot water is a very satisfactory heating medium because it produces a steady even heat. It is particularly adaptable to sections where long protracted cold spells are common and where coal fires are banked at night. Hot water systems should not be installed where the heating system is to be used intermittently. For example, if a ranger station may be used for two months of the winter and shut down for the rest of the time or used some days and not others, the proper heating system would be either gravity warm air or forced warm air.

Hot water systems are more expensive than hot air systems. Radiators should be placed under windows or adjacent to them for best results. Radiator sizes are calculated on the basis of square feet of heating surface.

In the "one pipe basement main" hot water system, radiators have two openings and two risers. The flow riser is tapped out of the top of the basement main and the return riser is brought into the bottom of the same main.

The two pipe basement main is usually the most satisfactory, and is not subject to the objection of the return water mixing with and cooling the outflowing hot water.

C. Steam Heating Systems.

Steam heating systems may be of various types, but the most economical for the average size building is the one-pipe gravity system. There is only one pipe connection to the radiator. Steam enters the radiator through this pipe, and water from the condensed steam returns to the boiler through the same pipe. It is important that the pipe be sloped because any sag which might permit water to cool will interfere with the steam flow and will usually cause a hammer in the system.

D. Heating Plant Accessories.

In many locations it will be economical and practical to burn wood in the heating plant. In such cases the furnace or boiler must be equipped with special wood burning grates of large capacity.

In some localities the use of oil burners is economical. Their operation is automatic. Their use provides extra space in the basement because of the elimination of the coal storage requirement.

Automatic stokers are sometimes practicable where coal burning heating systems are used. Stoker installations should be made strictly in accordance with the manufacturer's instructions.

References:

Pencil Point Data Sheets - Don Graf

CHAPTER XXII - ELECTRIC SERVICE

204. Requirements and Planning.

Some Forest Service structures are located in places which afford commercial electric service, while others are located where it may be necessary and desirable to install electric lighting plants. The material in this chapter will be of help in planning and installing the proper electric facilities. There are many definite requirements of workmanship and materials which must be met. The electricians should begin their work at the proper stage of construction, so that conduits, outlet boxes, switches, etc., may be placed without interfering with the other construction work.

Electrical wiring and equipment are indicated by symbols on Forest Service plans. The symbols shown on Pages 340 and 341 are given to assist in reading the plans.

All plans for new buildings and structures should indicate the necessary wiring and equipment.

A. Service Wires.

Service wires, unless run underground, must be brought down on the outside of the house, then through the wall and into the service switch box or cabinet, protected against water and weather. Rigid conduits are extensively employed for the purpose of enclosing the wires. Ordinary armored cable or flexible metal conduit should not be used. In consideration of improved appearance, it may be desirable to run service wires underground from the point of connection to the structure. This may also be done between buildings. The wire should be enclosed in BXL armored cable or encased in a lead sheath for protection against moisture.

An effort should be made to abide by the codes and rules of the local electric power service company when connections are made between their lines and Forest Service buildings. If no code prevails, comparable conditions as covered by the National Electric Code of the National Board of Fire Underwriters should be followed.

B. Grounding.

Grounding is an important precaution against fire and lightning hazards. Grounding consists of a good connection between one of the service wires or a grounded neutral, and a water pipe or a rod driven into the ground. A connection to water pipes supplied from city mains or running water systems is always preferable. When a connection is made to a water supply from city mains it should be on the street side of the meter. The grounding connection should be a noncorrosive wire no smaller than #8, securely clamped to the water pipe or ground rod and well protected from mechanical injury. The ground-

ELECTRIC WIRING SYMBOLS

GENERAL OUTLETS

Ceiling	Wall	
○	-○	Outlet
Ⓒ	-Ⓒ	Capped Outlet
Ⓓ		Drop Cord
Ⓔ	-Ⓔ	Electrical Outlet (For use only when circle used alone might be confused with columns, plumbing symbols, etc.)
Ⓕ	-Ⓕ	Fan Outlet
Ⓙ	-Ⓙ	Junction Box
Ⓛ	-Ⓛ	Lamp Holder
$Ⓛ_{PS}$	$-Ⓛ_{PS}$	Lamp Holder with Pull Switch
Ⓢ	-Ⓢ	Pull Switch
Ⓥ	-Ⓥ	Outlet for Vapor Discharge Lamp
Ⓧ	-Ⓧ	Exit Light Outlet
Ⓒ	-Ⓒ	Clock Outlet (Lighting Voltage)

CONVENIENCE OUTLETS

⇌	Duplex Convenience Outlet
$⇌_{1,3}$	Convenience Outlet other than Duplex 1 = Single, 3 = Triplex, etc.
$⇌_{WP}$	Weatherproof Convenience Outlet
$⇌_{R}$	Range Outlet
⇌-$	Switch and Convenience Outlet
⇌-R	Radio and Convenience Outlet
ⓐ	Special Purpose Outlet (Describe in Spec.)
◉	Floor Outlet

SWITCH OUTLETS

$	Single Pole Switch
$2	Double Pole Switch
$3	Three Way Switch
$4	Four Way Switch
$D	Automatic Door Switch
$E	Electrolier Switch
$K	Key Operated Switch
$P	Switch and Pilot Lamp
$CB	Circuit Breaker
$WCB	Weatherproof Circuit Breaker
$MC	Momentary Contact Switch
$RC	Remote Control Switch
$WP	Weatherproof Switch

SPECIAL OUTLETS

○ a,b,c-etc.
⇌ a,b,c-etc.
$ a,b,c-etc.

Any Standard Symbol as given above with the addition of a lower case subscript letter may be used to designate some special variation of standard equipment of particular interest in a specific set of architectural plans.

When used they must be listed in the key of symbols on each drawing and if necessary, further described in the specifications.

Symbols prepared by a technical subcommittee of A.S.A., Committee Z32.

ELECTRIC WIRING SYMBOLS

PANELS
CIRCUITS & MISCELLANEOUS

Lighting Panel

Power Panel

Branch Circuit - Ceiling or Wall

Branch Circuit - Floor

Note: Any circuit without further designation indicates a two-wire circuit. For a greater number of wires indicate as follows: -|||- (3 wires), -||||- (4 wires), etc.

Feeders

Note: Use heavy lines and designate by number corresponding to listing in Feeder Schedule.

Underfloor Duct and Junction Box - Triple System

Note: For Double or Single Systems eliminate one or two lines. This symbol is equally adaptable to auxiliary system layouts.

G Generator

M Motor

I Instrument

T Transformer

Controller

Disconnect Switch

AUXILIARY SYSTEMS

Push Buttons

Buzzer

Bell

Annunciator

Telephone

Telephone Switchboard

Clock (Low Voltage)

D Electric Door Opener

F Fire Alarm Bell

F Fire Alarm Station

City Fire Alarm Station

FA Fire Alarm Central Station

FS Automatic Fire Alarm Device

W Watchman's Station

WI Watchman's Central Station

H Horn

N Nurse's Signal Plug

M Maid's Signal Plug

R Radio Outlet

SC Signal Central Station

Interconnection Box

Battery

Auxiliary System Circuits

Note: Any line without further designation indicates a two-wire circuit. For a greater number of wires designate with numerals in manner similar to — - — 12# 18W-$\frac{3}{4}$"C, or designate by number corresponding to listing in schedule

SPECIAL OUTLETS

$\square_{a,b,c\text{-}etc.}$ Note: Sub-script letters refer to notes on plans or detailed description in specifications.

Symbols prepared by a technical subcommittee of A.S.A., Committee Z32.

ing wire may be placed in a rigid conduit for protection against mechanical injury. In this case both the conduit and the wire should be connected to the ground rod. The actual connection, usually a ground clamp, should be examined to make sure that it is tight and that the electrical contact is not made ineffective by dirt or corrosion. Where wiring is installed in a metal conduit it is good practice to ground the conduit system to the water pipe or ground rod through a separate ground wire.

C. Interior or Branch Circuits.

Service wires lead from the power line to a cabinet where the main switch and main fuses are located. There should be no fuses in the grounded conduits. Several branch wiring circuits are extended from the cabinet to the various rooms of the building or parts of the structure. The number of these circuits depends upon the size of the house, and the number and arrangement of the lighting appliances or power outlets. The sizes of the wires used in the circuits depends upon the quantity of the electrical current they are to carry.

Electrical authorities recommend one branch circuit for each 500 square feet of floor area in all finished rooms and enclosed porches. The total area may be computed by multiplying the outside dimensions of the building by the number of finished floors. The total area should be divided by 500 to obtain the necessary number of lighting circuits. Additional circuits should be provided to carry current for appliances, such as kitchen ranges, and other special equipment. These special circuits will usually be of heavier wire, because of the large amount of electric power required by the equipment they are to serve.

D. Fuses.

Fuses are like safety valves. When the circuits become overloaded the wires heat up quickly. Fuses that melt at a low temperature and break the circuit are inserted into the line to avert the possibility of hot wires setting fire to a building. Each branch circuit should be separately fused, and no fuse should have a capacity of over 15 amperes. The fuses should be located in the service cabinet. Multi-breakers approved by the National Electrical Code may be used instead of fuses.

E. Outlets.

A lighting outlet is intended for the direct connection of a lampholder, a lighting fixture, or a pendant cord terminating in a lampholder. A receptacle outlet is equipped with one or more receptacles, not of the screw shell type, intended to receive attachment plugs.

F. Polarity Identification.

All interior wiring systems, unless otherwise excepted, should have a grounded conductor which is continuously identified throughout the system. The identified conductor of each branch circuit should be

connected to each lamp or appliance on the circuit. Unidentified two-wire branches may be tapped from the ungrounded wires of multi-wire circuits having an identified neutral on the premises, if over-current protection is provided in both wires and if no single-pole switching devices or key sockets are used on branch circuits.

The National Electrical Code covers this subject more fully and should be referred to when doubt exists as to the procedure to follow.

G. Demand Calculations of Feeder Sizes.

The "demand factor" of any system or part of a system, is the ratio of the maximum demand to the total connected load.

The "demand load" is the load which may reasonably be expected for the type of occupancy under consideration and is computed on the basis of watts for the area and occupancy.

The word "area" means gross area, which is determined by the outside dimensions of the building and by the number of floors. Cellars, unfinished attics, open porches, and other spaces not used as living quarters, need not be included in this computation.

The word "feeder" refers to all conductors of an interior wiring system up to the final distribution center and includes the service entrance conductors and the conductors between buildings.

Voltage drop due to length of feeders has not been considered. It is recommended that the outside feeder conductors shall be of such a size as to cause not more than 3% voltage drop up to the final distributing point on any feeder after the demand, if any, has been applied.

The values and demands given in this article apply to an interior wiring system which supplies lights and appliances, but does not include capacity for industrial apparatus requiring special circuits.

The values and demands are based on average load conditions. If at any time it is found that the conductors will be, or are, overloaded, they shall be increased to comply with the requirements of the table on Page 347.

(a) Method of Calculation.

The total current in amperes for all loads shall determine the size of feeders, in accordance with the table on Page 347.

For a lighting and appliance load, the current in amperes shall be not less than required for the demand load.

For a combined lighting and appliance load and a power load, the current in amperes for the lighting and appliance load shall be that required for the demand load, determined as specified in the above paragraph.

The minimum requirements for watts or fractions of watts per unit of area, and the demand factor applying thereto for each kind of building and occupancy served are as specified in the following sub-paragraphs. The required minimum demand load shall be the computed load as determined herein, multiplied by the indicated demand.

(1) Single Family Dwellings.

The wattage requirement is one watt per square foot, plus 1000 watts for small appliances.

For an area of 2,000 square feet or less, the demand factor is 100 percent. For all areas in excess of 2,000 square feet, the demand factor is 60 percent.

No demand factor shall be applied in connection with small appliance loads.

(2) Multi-Family Dwellings.

The wattage requirement is one watt per square foot, plus 1000 watts per apartment for small appliances.

For wattages of 2000 or less, the demand factor is 100 percent.

For that part of the wattage in excess of the first 2000 watts, the demand factor is 70 percent, provided the number of apartments does not exceed ten. The demand for each feeder shall be determined by the area and the number of apartments supplied.

Demand factors shall not be applied to small appliance loads when computing the sizes of sub-feeders to individual apartments. Demand factors may be applied to combined lighting and appliance loads when computing the sizes of mains and feeders other than the sub-feeders to individual apartments.

(3) Office Buildings.

The wattage requirement is two watts per square foot. For areas of 10,000 square feet or less per feeder the demand factor is 100 percent.

For all areas in excess of 10,000 square feet per feeder, the demand factor is 70 percent.

(4) Cooking and Baking Appliances.

The sizes of feeders supplying cooking and baking appliances, each rated at more than 1650 watts, may be determined on the basis of the demand values shown on Page 345.

Number of Ranges	Demand Factor Percent
1	80
2	75
3	70

The following examples illustrate the application of the requirements listed. In these examples the 2-wire system has been used solely for simplicity of illustration. The same general method of calculation may be applied to other systems of distribution, such as 3, 4, or 5-wire.

(b) Example of Calculations.

A dwelling having an area of 4500 square feet, exclusive of unoccupied cellars, unfinished attics, and open porches.

Area in Square Feet, 4500 x 1 watt per sq. ft. = 4500 watts

Allowance for appliances = 1000 watts

Computed Load = 5500 watts

Demand Factors Selected for This Occupancy

First 2000 square feet--Demand factor 100 percent
Excess above 2000 square feet--Demand factor 60 percent
Total area--4500 square feet

2000 square feet at 1 watt per sq. ft. x 1 = 2000 watts
2500 square feet at 1 watt per sq. ft. x 0.6 = 1500 watts
Allowance for appliances = 1000 watts

Load after Applying Demand Factor = 4500 watts

Size of conductors selected from table on Page 347.

For 110 volt, 2-wire system:
4500 watts ÷ 110 volts = 40.9 amperes
Size of conductors = No. 6 for each wire

For 220 volt, 2-wire system:
4500 watts ÷ 220 volts = 20.45 amperes
Size of conductors = No. 10 for each wire

For 110-220 volt, 3-wire system:
4500 watt ÷ 2 x 110 volts = 20.45 amperes
Size of conductors = No. 10 for each wire

For 120-208 volt, 4-wire, 3-phase system:
4500 watt ÷ 3 x 120 volts = 12.5 amperes
Size of conductors = No. 14 for each wire

The above calculation does not take into account ranges or other appliances using more than 1650 watts each.

GUIDE TO THE AMOUNT OF WATTS REQUIRED FOR DIFFERENT EQUIPMENT

	Watts
Air Conditioning Controls	650
Clocks	2
Cooker	475
Curling iron	20
Coffee maker	550
Dish washer	125
Electric blower for heating system	75
Electric refrigerator	200 to 500
Egg cooker	420
Flat iron	600 to 1,000
Floor waxer	50
Grill	475
Hair dryer	50
Heating pad	60
Mixer	70
Oil burner motor	125
Oil burner, including ignition and controls	500
Pressure pump	500
Radio	100
Sewing machine	65
Sump pump	200
Sun lamp	400
Toaster	500
Vacuum cleaner	250
Vent fan	50
Waffle iron	700
Washer	100 to 400
Water pump motor	200
Automatic garage doors	200
Clothes drier	4,000
Electric range	4,000 to 14,000
Electric water heater	1,500 to 3,000

GUIDE FOR COMPUTING WATTAGE FOR OUTLETS FOR LIGHTS FOR SPECIFIC CLASS OF OCCUPANCY

	Watts per sq. ft. for general illumination	
	Best practice	Minimum good practice
Drafting Room, no local illumination	5	3
Warehouse or Shop (with additional bench illumination)	2.4	1.2

GUIDE FOR COMPUTING WATTAGE FOR OUTLETS FOR LIGHTS FOR SPECIFIC CLASS OF OCCUPANCY (CONTINUED)

	Watts per sq. ft. for general illumination	
	Best practice	Minimum good practice
Garage - dead storage	.6	.4
" - live storage	1.6	1.1
Repair Shop - wash racks	3	2
" " - gasoline and oil houses and dispensaries	3	2
Offices, general (where well daylighted)	2.4	1.6
Offices, otherwise	3	2
Kitchens	3	2½
Stairs	1½	1
Toilets	1½	1
Living Rooms	3	2
Laboratories	3	2½

TABLE OF ALLOWABLE CARRYING CAPACITIES OF CONDUCTORS

Gage No.	Diameter of Solid Wires in Mils	Area in Circular Mils	Column A Rubber Insulation Amperes	Column B Varnished Cambric Insulation Amperes	Column C Other Insulation and Bare Conductors Amperes
18	40.3	1,624	3		6*
16	50.8	2,583	6		10*
14	64.1	4,107	15	18	20
12	80.8	6,530	20	25	30
10	101.9	10,380	25	30	35
8	128.5	16,510	35	40	50
6	162.0	26,250	50	60	70
5	181.9	33,100	55	65	80
4	204.3	41,740	70	85	90
3	229.4	52,630	80	95	100
2	257.6	66,370	90	110	125
1	289.3	83,690	100	120	150

*The allowable carrying capacities of No. 18 and No. 16 are 10 and 15 amperes, respectively, when in cords for portable heaters.

1 Mil = 0.001 inch.

Conductors, whether solid or stranded, should not be of smaller size than No. 14, except that conductors of sizes Nos. 18 and 16 may be used for flexible cords and for fixture wires.

H. Branch Circuits - 15-Ampere.

Fifteen-ampere branch circuits may supply lighting outlets, receptacle outlets, permanently connected appliances, or any desired combination of such loads, and shall comply with the following:

(a) Wires smaller than No. 12 shall not be used.

(b) Automatic overcurrent protective devices shall have a rating or setting not exceeding 15 amperes at 125 volts or less, and not exceeding 10 amperes at 250 volts.

(c) Such circuits shall not be used to supply any appliance rated at more than 1320 watts.

I. Appliance Branch Circuits.

Appliance branch circuits shall supply only permanently connected appliances or receptacle outlets or a combination of the two and shall comply with the following:

(a) Wires smaller than No. 12 shall not be used.

(b) Automatic overcurrent protective devices shall have a rating or setting not exceeding 25 amperes.

(c) Receptacle outlets on appliance branch circuits shall be fitted with receptacles rated at 15 amperes. No appliance rated at more than 1650 watts shall be supplied by such a branch circuit.

(d) In residential occupancies, the voltage to the ground of an appliance branch circuit shall not exceed 150, and one of the conductors supplying each portable appliance shall be a grounded conductor. The requirement of this sub-paragraph does not apply to occupancies other than residential.

(e) The total current in amperes of the connected load shall not exceed the rating or setting of the overcurrent protective device. Not less than 1-1/2 amperes shall be assumed as the connected load for each receptacle outlet.

J. Minimum Safety Provisions.

The provisions of sub-paragraphs (a) and (b) are recommended for planning a suitable number of outlets and for calculating the required circuit capacity.

(a) Small Residences.

At least one receptacle outlet should be installed in each room. It is preferable that a sufficient number be installed to provide that no point on the wall, measured horizontally, will be more than 15 feet distant from such an outlet. At least one receptacle outlet should be installed near to each permanently installed laundry tub.

(b) Multi-Family Residences.

One or more appliance branch circuits should be installed to supply receptacle outlets in each space intended for the use of a single family. These should be in the kitchen, pantry, dining room, and breakfast room, and adjacent to permanently installed laundry tubs. Any such outlet may be supplied by an individual appliance branch circuit. In addition to supplying receptacle outlets, an appliance branch circuit may also supply one or more permanently connected appliances in these rooms. It may also supply an electric refrigerator or other appliance operated by a motor rated at not more than 6 amperes, but no larger motor load shall be supplied by such an appliance branch circuit.

It is desirable to have sufficient outlets or connections in the various rooms, halls, and passageways, with the necessary switches located in convenient places and positions. All convenience outlets, except in floors or where contrary to code regulations should be duplex receptacles for portable appliances, such as washing machines, irons, refrigerators, etc., be equipped with three wire plugs. All switches should be of the flush type.

Switches and lighting fixtures should be vapor-proof where they are installed in locations exposed to gases or extreme moisture.

205. Wiring Methods.

This article describes only the types of wiring and the methods of installation which are recognized as suitable.

Local wiring codes must be followed. Where no known code exists, it is suggested that all work be in accordance with the regulations of the National Board of Fire Underwriters for electrical wire and apparatus, as recommended by the American Standards Association. Information and specifications under these regulations are available in N.B.F.U. pamphlet #37, 1935, National Electric Code of the National Board of Fire Underwriters.

Federal Specifications for electrical materials should be used where possible. The following specifications apply as designated:

Federal Specification J-C-101a - Cable and Wire; Rubber Insulated, Building Type, Code - Grade

Federal Specification WW-C-581a - Conduit; Steel, Rigid, Zinc Coated
Federal Specification WW-T-806a - Tubing; Electrical, Metallic

A. Knob and Tube Wiring.

Knob and tube wiring may be installed as open wiring in unfinished basements and attics. Elsewhere it is concealed in the spaces between joists and studs. In basements the exposed wires should be run through porcelain tubes placed in the center of the joists or upon porcelain knobs nailed on the sides of the joists. The wires should not be run on or across the lower edges of the joists where they might be knocked loose. Similar requirements apply to attics where the wires are likely to be damaged.

Knobs should not be spaced more than 4 feet apart and should be designed to maintain the conductor at least 1" from the surface of the wall. They should conform to the dimensions shown on Page 351.

Concealed knob and tube work should not be used for systems of more than 300 volts between the conductors or more than 150 volts to the ground. All knobs, tubes, and bushings should conform to the standards approved by the National Board of Fire Underwriters for this class of material.

Approved rubber-covered wire of a type meeting Federal Specification J-C-101a should be used. Conductors should be separated at least 2-1/2" and maintained at least 1/2" from the surface wired over, if the voltage does not exceed 300.

B. Non-Metallic Sheath Cable.

Non-metallic sheath cable which meets National Electrical Code requirements may be run through or on the sides of joists. When run on the sides of joists or studs, the cable should be secured in place with metal clips, spaced not more than 3 feet apart, and within 12 inches of each outlet box or fitting. Such conductors, when used in wet or damp places shall be lead sheathed and rubber covered. This type of cable should not be installed in masonry or concrete, or be buried in plaster. Thermal insulation of approved non-corrosive, non-combustible materials may be used in narrow spaces of walls or ceilings in which such cable is installed. Such thermal insulation should be so installed that strain will not be placed on the cables, cable supports, or terminal connections.

Cables should be protected against mechanical injury where necessary, by rigid conduit or pipe, or by substantial guard strips. Where cable passes through floors, it should be enclosed by rigid conduit or pipe extending at least 6" above the floor. Bends in cables should have a radius of not less than 5 times its internal diameter. When cable is used for exposed or concealed wiring it should be run through holes in studs, joists, or other wood members which have been bored in the approximate center of such timbers or at least 2" from the nearest edge.

KNOB SIZES

Size of Conductor Inclusive	Size of Base, Inches			Solid Knobs, Groove, Inches		
	Circular Knobs, Diameter	Square Knobs or single Wire Cleats				
		Width	Length	Depth	Diameter	Split Knobs, Thickness of Cap
14-10	1-1/8	3/4	1-3/4	3/16	1/4	3/8
8-4	1-1/2	7/8	2	5/16	5/16	5/8
2-00	2	1	2-1/4	7/16	5/8	5/8
000-300,000 C.M.	2-1/2	1-1/8	2-3/4	7/16	25/32	7/8
400,000-1,000,000 C.M.	3	1-3/8	3-3/4	5/8	1-1/4	1

Inches from Top of Wire Groove

TWO-WIRE AND THREE-WIRE SYSTEMS

Size of Conductor	Number of Conductors in One Conduit								
	1	2	3	4	5	6	7	8	9
	Minimum Size of Conduit in Inches								
No. 14	½	½	½	½	¾	¾	¾	1	1
12	½	½	½	¾	¾	1	1	1	1¼
10	½	¾	¾	¾	1	1	1¼	1¼	1¼
8	¾	¾	1	1	1¼	1¼	1¼	1¼	1½
6	¾	1	1¼	1¼	1½	1½	2	2	2
5	1	1¼	1¼	1¼	1½	2	2	2	2
4	1¼	1¼	1¼	1½	2	2	2	2	2½
3	1¼	1¼	1¼	1½	2	2	2	2½	2½
2	1¼	1¼	1½	1½	2	2	2½	2½	2½
1	1½	1½	1½	2	2	2½	2½	3	3
0	1	1½	2	2	2½	2½	3	3	3
00	1	2	2	2½	2½	3	3	3	3½
000	1	2	2	2½	3	3	3	3½	3½
0000	1¼	2	2½	2½	3	3	3½	3½	4

WIRING TABLES

TWO PER CENT LOSS ON 110 VOLTS

Capacity Amperes	Distance in Feet to Center of Distribution								
	20	30	40	50	60	70	80	90	100
1	..	..	..	..	..	..	..	..	..
1.5	..	..	..	..	..	..	..	..	..
2	..	..	..	..	..	..	..	..	..
3	..	..	..	..	..	..	16	15	15
4	..	..	..	..	16	15	15	14	14
5	..	..	..	16	15	14	14	13	13
6	..	..	16	15	14	14	13	12	12
7	..	16	15	14	14	13	12	12	11
8	..	16	15	14	13	12	12	11	11
9	..	15	14	13	12	12	11	11	10
10	16	15	14	13	12	11	11	10	10
12	16	14	13	12	11	11	10	9	9
14	15	14	12	11	11	10	9	9	8
16	15	13	12	11	10	9	9	8	8
18	14	12	11	10	9	9	8	8	7
20	14	12	11	10	9	8	8	7	7
25	13	11	10	9	8	7	7	6	6
30	12	10	9	8	7	7	6	6	5
35	11	10	8	7	7	6	5	5	4
40	11	9	8	7	6	5	5	4	4
45	10	9	7	6	6	5	4	4	3
50	10	8	7	6	5	4	4	3	3
60	9	7	6	5	4	4	3	3	2
70	8	7	5	4	4	3	2	2	1
80	8	6	5	4	3	2	2	1	1
90	7	6	4	3	3	2	1	1	0
100	7	5	4	3	2	1	1	0	0
120	6	4	3	2	1	1	0	0	00

Capacity Amperes	Distance in Feet to Center of Distribution								
	120	140	160	180	200	240	280	320	360
1	..	..	..	..	..	16	15	15	14
1.5	..	..	16	15	15	14	14	13	12
2	16	15	15	14	14	13	12	12	11
3	14	14	13	12	12	11	11	10	9
4	13	12	12	11	11	10	9	9	8
5	12	11	11	10	10	9	8	8	7
6	11	11	10	9	9	8	8	7	7
7	11	10	9	9	8	7	7	6	6
8	10	9	9	8	8	7	7	6	5
9	9	9	8	8	7	7	6	5	5
10	9	8	8	7	7	6	5	5	4
12	8	8	7	7	6	5	5	4	4
14	7	7	6	6	5	5	5	3	3
16	7	7	6	5	5	4	3	3	2
18	7	6	5	5	4	4	3	2	2
20	6	5	5	4	4	3	2	2	1
25	5	4	4	3	3	2	1	1	0
30	4	4	3	3	2	1	1	0	0
35	4	3	2	2	1	1	0	00	00
40	3	2	2	1	1	0	00	00	000
45	3	2	1	1	0	00	00	000	000
50	2	1	1	0	0	00	000	000	0000
60	1	1	0	00	00	000	000	0000	0000
70	1	0	00	00	000	000	0000	0000	....
80	0	00	00	000	000	0000	0000	....	....
90	00	00	000	000	0000	0000	....	....	....
100	00	000	000	0000	0000	....	....	....	....
120	00	000	0000	0000	....	....	....	....	....

WIRING TABLES

TWO PERCENT LOSS ON 220 VOLTS

Capacity Amperes	Distance in Feet to Center of Distribution								
	20	30	40	50	60	70	80	90	100
1	..	..	..	..	..	..	..	..	..
1.5	..	..	..	..	..	..	..	..	..
2	..	..	..	..	..	..	..	..	..
3	..	..	..	..	..	..	..	..	..
4	..	..	..	..	..	..	..	..	..
5	..	..	..	..	..	..	..	..	16
6	..	..	..	..	..	..	16	15	15
7	..	..	..	..	..	16	15	14	14
8	..	..	..	..	16	15	15	14	14
9	..	..	..	..	15	15	14	14	13
10	..	..	..	16	15	14	14	13	13
12	..	..	16	15	14	14	13	12	12
14	..	16	15	14	14	13	12	12	11
16	..	16	15	14	13	12	12	11	11
18	..	15	14	13	12	12	11	11	10
20	16	15	14	13	12	11	11	10	10
25	16	14	13	12	11	10	10	9	9
30	15	13	12	11	10	10	9	9	8
35	14	13	11	10	10	9	8	8	7
40	14	12	11	10	9	8	8	7	7
45	13	12	10	9	9	8	7	7	6
50	13	11	10	9	8	7	7	6	6
60	12	10	9	8	7	7	6	6	5
70	11	10	8	7	7	6	5	5	4
80	11	9	8	7	6	5	5	4	4
90	10	9	7	6	6	5	4	4	2
100	10	8	7	6	5	4	4	3	3
120	9	7	6	5	4	4	3	3	2

Capacity Amperes	Distance in Feet to Center of Distribution								
	120	140	160	180	200	240	250	320	360
1	..	..	..	..	..	..	..	..	..
1.5	..	..	..	..	..	..	..	16	15
2	..	..	..	..	..	16	15	15	14
3	..	..	16	15	15	14	14	13	12
4	16	15	15	14	14	13	12	12	11
5	15	14	14	13	13	12	11	11	10
6	14	14	13	12	12	11	11	10	9
7	14	13	12	12	11	11	10	9	9
8	13	12	12	11	11	10	9	9	8
9	12	12	11	11	10	9	9	8	8
10	12	11	11	10	10	9	8	8	7
12	11	11	10	9	9	8	8	7	7
14	11	10	9	9	8	7	7	6	6
16	10	9	9	8	8	7	7	6	6
18	9	9	8	8	7	7	6	5	5
20	9	8	8	7	7	6	5	5	4
25	8	7	7	6	6	5	4	4	3
30	7	7	6	6	5	4	4	3	3
35	7	6	5	5	4	4	3	2	2
40	6	5	5	4	4	3	2	2	1
45	6	5	4	4	3	3	2	1	1
50	5	4	4	3	3	2	1	1	0
60	4	4	3	3	2	1	1	0	0
70	4	3	2	2	1	1	0	00	00
80	3	2	2	1	1	0	00	00	000
90	3	2	1	1	0	00	00	000	000
100	2	1	1	0	0	00	000	000	0000
120	1	1	0	0	00	000	000	0000	0000

C. Armored Cable and Flexible Conduit.

Armored cable and flexible metal conduit can be recognized by the spirally wound metallic exterior covering. This type of wiring may be used in any dry location. In continuously damp locations a special cable having a continuous lead covering over the wires inside the spiral must be used. In accessible attics, the cable should be protected from mechanical injury at all locations within 5 feet of the floor. Where it is exposed it should be secured in place with metal clips spaced about 2 feet apart. Where a conduit is installed in locations exposed to corrosive fumes or vapors, the conduit and fittings should be of a corrosive-resistant material suitable for the conditions under which it is used.

Bends of flexible metallic conduit should be made so that the conduit will not be injured. The radius of the curve of any bend should be not less than 6 times the internal diameter of the conduit. Care should be taken at all times to make certain that the internal diameter of the conduit is not reduced at the bend. Threadless type connectors and couplings used with conduits should always be made up tight. When they are buried in concrete or used in rooms they should be of an approved water-proof type.

D. Rigid Metal Conduit.

Rigid metal conduit is pipe in which the wires are carried. Where it is exposed in the basement, it should be installed either across the lower edges or on the sides of the joists and should be secured in position by metal strips placed about 5 feet apart. The conduit should be of an approved type, and no conduit smaller than 1/2" electrical trade size should be used. Rigid conduit is usually in standard lengths of 10 feet, including the coupling. One coupling is usually furnished with each length. Both ends should be threaded and reamed.

Bends of rigid conduit should be made so that the conduit will not be injured and so that the internal diameter is not reduced. Bends should be made with a radius not less than 6 times the internal diameter. A run of conduit between outlet and outlet, between fitting and fitting, or between outlet and fitting, shall not contain more than the equivalent of four quarter-bends, including those bends at the outlet or fitting.

All bends of conduit should be reamed to remove the rough edges. An approved bushing should be provided to protect the conductor from abrasion where a conduit enters a box or other fitting. One conduit should not contain more conductors than specified in the table on Page 351. The table applies only to complete conduit systems, and does not apply to short sections of conduit used for the protection of exposed wiring from mechanical injury.

206. Electric Fixtures.

Electric fixtures must be appropriate in utility and appearance and must have a finish that will match well with existing work. The fixtures should also be of an approved standard of construction.

It is suggested that fixtures for Forest Service buildings be held as nearly as possible to simple designs. Fixtures for use in dwellings and offices should be chosen with the idea that they will be an appropriate match to the building and to the interior furnishings.

A. Lighting Fixtures.

Lamp holders installed over exposed inflammable material should be of the keyless type with no live wires exposed. Unless individual switches are provided, they should be located at least 7-1/2 feet above the floor, and should be otherwise so located and guarded that the lamps cannot readily be backed out by hand.

No connecting conductor should be smaller than #18. Stranded conductors should not be used on chains or other movable parts, unless the wires are completely enclosed in metal. The conductors should be protected from abrasion where they pass through sheet metal chains or clamps, which may be a part of the fixture. No splice or tape should be located within an arm or a stem. Each fixture should be so wired that all screw chains or lamp holders are connected to the same supply wire or terminal. Chain fixtures should be wired with flexible conductors so that the weight of the fixture will not put tension on the conductor. All fixture wiring must be free from short circuits and grounds and should be tested for these defects prior to being connected to the circuit.

B. Lamp Holding Devices.

Lamp holding devices should be so designed and installed that no current-carrying parts will be normally exposed externally.

Lamp holders should be installed on the ceiling or on the wall above the door in clothes closets. Ungrounded metal lamp holding devices should not be installed near bathtubs or showers. Metal pulls should never be used in bathrooms. Inflammable cord leads of portable lamps should be equipped with handle sockets and substantial guards.

Water-proof lamp holding devices especially approved for the locations should be employed in damp or wet places or where corrosive vapors exist. If not attached to fixtures, medium or normal bases of lamp holding devices should be held on wires not less than #14 which are soldered directly to the circuit wires but supported independently.

When intermediate or candelabra base lamp holding devices are installed in this manner, the wires, except for approved Christmas tree and decorating outfits, should not be smaller than #18. It is recommended that these wires be twisted together if the pendant is

longer than 3 feet. Flush receptacles should be enclosed in approved metal boxes in addition to the insulated enclosures of the mechanism. Attachment plugs and receptacles located in floors should be enclosed in approved metal boxes especially designed for the purpose.

Receptacles of the screw shell type should be installed only for use as lamp holders. Receptacles installed for portable cords should be screw shell base devices.

Fixtures involving some weight will usually be furnished with a fixture fastening device of some form of crowfoot or bracket. Only fasteners of an approved style and type should be used. These should be such as to afford ample security for the fixture and sufficient strength in reserve to offset handling or any strains that may come upon the fixture itself.

C. Rosettes.

Rosettes designed for use with exposed wiring, must be provided with bases which should have at least two holes for supporting screws, should be high enough to keep the terminals at least 1/2" from the surface wire, and should have a porcelain lug over each terminal to prevent the rosette from being placed over projections which would reduce the space to less than 1/2".

Rosette bases should be high enough to keep the wires and terminals at least 3/8" from the surface wired over. Fuseless rosettes should be rated at 660 watts, 250 volts, and a maximum current rating of 6 amperes. Fused rosettes should not be installed.

Wires connected to lamps or appliances should have an approved insulated covering with heat-resisting qualities consistent with the temperature to be encountered. The specifications of the National Board of Fire Underwriters for flexible cords will be safe to follow.

207. Electric Lighting Plants.

Electric lighting plants should be selected so that they will afford a sufficient output to properly handle the loads to which they will be subjected. As a rule, it will be desirable to install plants which generate an alternating current of 110 volts and which are automatic in starting at the turn of a switch anywhere in the system.

With such plants, standard attachments and appliances of all kinds can be used, and it will not be necessary to purchase lamps, attachments, or appliances which have special voltage capacities. Storage battery plants require considerable attention and the batteries must be renewed at regular intervals at a considerable cost. Should battery systems be used, the batteries should be located in spaces having natural means of ventilation. Battery jars and cells, if not composed of insulating material such as glass or hard rubber, should be mounted on insulating supports of glass or porcelain. The grounding of frames or engines of generators is not required.

When wires are run overhead between buildings one of the circuit wires should be grounded. The fuses in any branch circuit should not exceed 20 amperes except for special circuits to which appliances or appliance receptacles are attached.

References:

National Board of Fire Underwriters 1935 "National Electrical Code", N.B.F.U. Pamphlet #70
How to Judge a House - U. S. Department of Commerce Wood Utilization
Pencil Points - Don Graf
Federal Specifications

CHAPTER XXIII - PLUMBING

208. Scope of Work

Plumbing facilities will be provided as shown in the plans. No job should be handled without competent labor. All plumbing work shall be considered as occurring in three stages:

A. Roughing-in - to include all the supply and drain service to point of fixture connection for waste; hot and cold water supply; gas supply, and the hot water heater, within the building and to a supply or waste connection just outside the building wall.

B. House supply and sewer - to include all supply and that portion of the drainage system extending from the building to the sewer or septic tank and disposal field and also the supply of water to the point of connection with the building.

C. Fixtures and their Placement - to include all water and plumbing fixtures within the building and their installation.

Stages A and C will be covered in this section as they affect the building. Stage B is covered in the Small Water Developments Handbook.

209. Definitions of Terms

House-sewer That portion of the drainage system extending from the building line to the sewer or septic tank.

House-drain The system of horizontal piping inside the building that extends to the house sewer. All soil, waste stacks and yard area and floor drains are connected to the house drain. Yard area and floor drains should not be connected to the house drain when a septic tank is used.

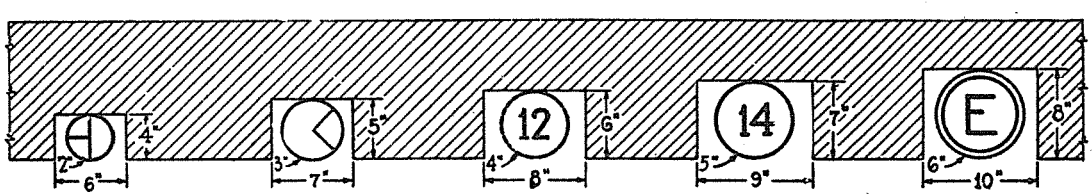
Soil-stacks The vertical lines which receive the discharge from water closets. Soil stacks may receive the discharge from other fixtures such as lavatories, sinks or bathtubs.

Soil-pipe The system of piping at the various floors which connects water closets to the soil stack.

Waste-stacks The vertical lines which receive the discharge of fixtures other than water closets.

CHARACTER	PLAN LINE	BAND INITIAL	BAND COLOR
Sanitary Sewerage		SAN	Blue
Soil Stack	24	SS	"
Waste Stack	11	WS	"
Vent Stack	18	VS	"
Combined Sewerage		CS	"
Storm Sewerage		STORM	Green
Roof Leader	E	RL	"
Indirect Waste		IW	"
Industrial Sewerage		IS	"
Acid or Chemical Waste		AW	"
Cold City Water		CW	White
Hot City Water		HW	"
Cir. Hot City Water		CR	"
Chilled Drinking Water		DW	"
Fire Line		FL	Red
Cold Industrial Water		CI	Yellow
Hot Industrial Water		HI	"
Cir. Hot Industrial Water		IR	"
Air		A	Gray
Gas		G	Brown
Oil		O	Black
Vacuum Cleaner		V	Cream
Local or Surface Vent		LV	Tan

SYMBOLS FOR EXPOSED PIPING



DIMENSIONS OF PIPE CHANNELS TO ACCOMODATE VARIOUS SIZE PIPES

COURTESY OF NATIONAL ASSOCIATION OF MASTER PLUMBERS

PLUMBING SYMBOLS

CHARACTER	PLAN	CHARACTER	PLAN	CHARACTER	PLAN	CHARACTER	PLAN
Corner Tub		R&L Drain Board, Kitchen Sink		Water Closet		Pedestal Lavatory	
Built In Tub		L.Hand Drain Board, Kitchen Sink		Wall Urinal		Wall Lavatory	
Roll Rim Tub		Plain Kitchen Sink		Pedestal Urinal		Corner Lavatory	
Shower Stall		Wash Sink	W. S.	Stall Urinal		Manicure Lavatory	
Sitz Bath	S.B.	Slop Sink	S.S.	Trough Urinal		Dental Lavatory	D.LAV.
Foot Bath	F.B.	Laundry Trays		Hose Rack	H.R.	Pedestal Drinking Fountain	DR.F
Bidet	B	Combination Sink & Tray	S. T.	Hose Bib	H.B.	Wall Hung Drinking Fountain	DR.F
Hot Water Tank	H.W. T.	Combination Sink & Dishwasher		Gas Outlet	G.		
Water Heater	W.H.	Washing Machine	W.M.	Vacuum Outlet	VAC.		

SYMBOLS FOR PLUMBING FIXTURES

CHARACTER	PLAN	CHARACTER	PLAN	CHARACTER	PLAN
Floor Drain	DR.	Floor Drain with Backwater Valve	DR.	Cleanout	CO
Shower Drain	DR.	Refrigerator Dr.	DR.	Grease Seperator	G.S.
Garage Drain	DR.	Roof Sump	S.	Oil Seperator	O.S.

DRAIN SYMBOLS

COURTESY OF NATIONAL ASSOCIATION OF MASTER PLUMBERS

PLUMBING SYMBOLS

Waste pipe The system of piping at the various floors which connects fixtures other than water closets to the soil or waste stack or to a soil pipe.

Vent-stacks They supply the drainage system with air to prevent syphonage of traps and to relieve pressure within the system. A vent stack accompanies every soil or waste stack but receives no discharges. It is connected to the base of the accompanying stack by means of a "Y" below the lowest fixture, and to the upper part of the stack above the highest fixture by means of a "T" fitting, or it may extend independently through the roof. Vent stacks should always be located on inside partition walls unless conditions are such that this cannot be done.

All vertical stacks extend through the roof and are open to the atmosphere. This enables air to circulate through the system, tending to keep the pipes free from the accumulation of objectionable odors or gases. Vent stacks should not be located more than 30 inches from water closets.

Vent pipe The system of piping at the various floors which connects the soil or waste pipe to the corresponding vent stacks.

Trap A device which prevents the passage of sewer gas or air into the room and yet permits the free passage of liquids or solid matters that may be carried by the liquid. The depth of water through which gas must pass to effect a passage is termed the water-seal.

Floor Drain or Cellar Drain A fixture through which water is led to a house or other drain. Floor drains are advisable only where a water-seal is assured in the trap.

Back-water Trap The purpose of this fitting is to prevent water due to floods or other cause from backing up into fixtures or basements. These are made in automatic and manually operated types.

Sewage Ejector This is equipment made to eject sewage and to prevent sewage discharge from backing up into the system.

Branches to waste and soil lines are taken off with Y or T-Y fittings. If the runs are horizontal, long turn or long radius T-Y's are used. Short turn T-Y's are permissible for vertical stacks.

210. Specifications for Roughing-in Materials and Work

A. Cast-Iron Soil Pipe, Fittings and Connections should conform to Federal Specification WW-P-401. All soil, waste, vent and drain pipes inside of the building below the basement floor and outside of the building below the ground, including the main connection from the building to a point 5'0" outside the building wall should be medium or extra heavy cast-iron with coated fittings.

B. Sub-Drainage Connection Where desired, foundation drains may be connected to exterior sewers with a running trap on each connection.

C. Jointing Joints between cast-iron pipes and fittings should be made with a picked oakum gasket and pig lead. Pig lead must conform to Federal Specification QQ-L-171, Grade "A". Joints should be run full at one pouring and calked solid, flush with the hub. Joints between steel and cast-iron pipe should be made by screwing a ring or part of a coupling on end of the steel pipe and calking it into the cast-iron hub.

D. Wrought-iron or Steel Soil, Waste, Drain and Vent Pipe, Fittings and Connections should be Class 1, Type A, galvanized steel pipe with Class B malleable iron fittings in accordance with Federal Specifications WW-P-403 and WW-P-521. All soil, waste and vent pipes, above the basement floor or the ground should be as specified. Special "Upright Y" branches should be used where vents connect with furred spaces and in other places when required by structural or space conditions.

E. Soil, Waste, Vent and Drain Piping. Soil, waste, vent and drain piping should be of the size and run indicated on the drawings for the work. Pipes below the basement floor and the ground should be run at the grades noted on the drawings. Soil and waste pipes above the basement floor should be given a grade of 1/4" per foot, except where the pipe would materially reduce the head room. In such cases the grade should be reduced to not less than 1/10" per foot.

The soil and waste pipes shown and noted on the drawings should be extended as vent pipes, and should project above the roof line not less than 12 inches nor more than 18 inches. Where noted or indicated on the drawings, two or more vent pipes may be connected together and extended as one pipe. Connections of vent pipes will be made in the roof space or at least 4 feet above the floor on which the vented fixture is located, to prevent the use of any vent line as a waste line.

F. Cleanouts on Cast-iron Pipe should be installed below the basement floor where shown on the drawings. They will consist of a combination "Y" and one-eighth bend, with an extension if necessary, to place the cast brass ferrule and screw plug flush with the floor.

G. Cleanout Plugs on Wrought-iron Piping should be fitted in each vertical soil, vent and waste pipe just above the floor which connects to a drainage system below the ground or under the basement floor.

Screwed cast-brass plugs of the same size as the pipe should be fitted for cleanouts on pipes above the basement floor where shown or noted on the drawings.

H. Traps Running traps or P traps should be placed on connections from area cesspools, or on sewer connections. Traps should be made of extra-heavy cast-iron and of the hub-and-spigot pattern.

Running traps should have a cleanout on each side. They should be provided with brass calking ferrules and brass trap screws with countersunk heads. If the sewage disposal is by means of septic tanks, grease traps should be placed on the line from the kitchen sink.

I. Flashing Connection Roof openings for vent pipes may be flashed and soldered water-tight by using 6 pound lead flashings with a wide roof flange. The lead may extend up close around the vent pipe for 10 inches above the roof. A drilled and threaded, standard galvanized, cast-iron cap, one size larger than the vent pipe may be screwed to the vent pipe at the top line of the lead flashing to form a counter-flashing.

Galvanized metal flashing may be used where they are practical or where they are specified. This flashing will have to be carefully fitted and placed to prevent leaks around the vent pipe and between the vent and the roof.

J. Unions Unions must comply with Federal Specification WW-U-531, Type B.

K. Water Piping All water supply pipe and fittings should be made of galvanized steel, galvanized wrought iron, galvanized copper molybdenum iron, brass or copper as specified in the plans.

L. Wrought-iron Pipe, Fittings and Connections All water pipe outside of the buildings and below the ground, and extending through the exterior walls, should be Class A, galvanized wrought-iron pipe in accordance with Federal Specification WW-P-441, or galvanized copper molybdenum iron. Pipe fittings should be Type A, galvanized, in accordance with Federal Specification WW-P-501.

Nipples should be Type A, galvanized, in accordance with Federal Specification WW-N-351.

Each length of pipe, each coupling, and each nipple should have the name and trade mark of the manufacturer rolled thereon for identification.

All changes in pipe sizes should be made with reducing fittings.

M. Steel Water Pipe, Fittings and Connections Water pipe within the buildings should be of galvanized welded steel pipe Class 1, conforming to Federal Specification WW-P-403.

Fittings and connections should be Type A galvanized cast-iron or Class B, galvanized malleable iron, as required in Federal Specifications WW-P-501 and WW-P-521, respectively.

Nipples should be Type A, galvanized, according to Federal Specification WW-M-351.

Each length of pipe, each coupling, and each nipple should have the name and trade mark of the manufacturer rolled thereon for identification.

All changes in pipe sizes should be made with reducing fittings.

N. Brass or Copper Pipe, Fittings and Connections Except where noted below, water supply pipes, including all connections to hot water storage tanks, may be specified in brass and copper. If so specified they should be Grade A, standard weight, unfinished, brass complying with Federal Specification WW-P-351, or copper pipe complying with Federal Specification WW-P-377.

All exposed branch connections on water supply piping for toilet rooms, including valves and fittings, should be finished and chromium plated.

Fittings and couplings must comply with Federal Specification WW-P-448, either composition A or B.

O. Screw Joints on Water Pipe. No bending of pipes will be allowed where fittings can be used. All pipes should have the burr removed from the ends. Screw joints shall be made with taper threads conforming to Federal Specific tion GGG-P-351. Joints should be made perfectly tight by the use of a stiff mixture of graphite and oil applied with a brush to the male threads only.

P. Copper Tubing and Sweat Joints for Water Pipes Type L, hard drawn, seamless copper tubing complying with Federal Specification WW-T-799 may be used instead of steel pipe for cold water and brass or copper pipe for hot water, except for finished chromium plated pipe. Fittings for this pipe should be cast or wrought copper, made for sweat joints with copper tubing. Wrought fittings should have a wall thickness not less than that of the tubing with which they are used. Fittings should receive the tubing to a depth of not less than the nominal diameter of the tubing. Sweated joints should be made with a solder containing not less than 95 percent tin and 5 percent antimony.

Joints should be made only after both the tubing and the inner surface of the fittings have been cleaned and burnished bright with steel wool.

All exposed branch connections on water supply piping from the floor or wall to plumbing fixtures should be screw jointed, finished and chromium plated.

Q. Gas Piping Gas pipes should be standard weight, black, welded steel complying with Federal Specification WW-P-403, or copper molybdenum iron. Fittings should be Class A, malleable iron complying with Federal Specification WW-P-521.

Gas pipe should be installed and connected to gas-fired water heaters at locations indicated on the drawings. They should be capped, where indicated, for future connections to the gas supply.

Screw joints on gas piping should conform to that specified for water piping.

R. Valves All valves should be of the gate type where the service requires them to be either wide open or shut tight. Check valves will be used to control the direction of flow, but must be installed only in horizontal runs of pipe. All valves should be of brass, with screw ends, rough body and finished trimmings, except those on chromium-plated brass pipe. These should be chromium plated.

Brass for valves should have a minimum copper content of 80 percent and a maximum lead content of 5-1/2 percent. Gate valves should be of the solid wedge pattern, double seat, rising or non-rising stems with gland stuffing boxes and iron wheels. They should weigh not less than the following:

Size Inches	Weight Pounds
1/2	0.93
3/4	1.56
1	2.18
1-1/4	3.50
1-1/2	5.00
2	7.19
2-1/2 (screwed)	31.00
2-1/2 (flanged)	41.00
3 (screwed)	42.00
3 (flanged)	57.00
4 (screwed)	65.00
4 (flanged)	85.00

S. Pipe Sleeves Cast-iron, standard wrought iron or steel pipe sleeves should be provided for all pipe passing through basement walls, except pipe passing through water-proofed walls and pipe hydrants and discharge nozzles or interior down spouts which discharge at grade. They must be properly secured in place, with approximately 1/4 inch space all around, between the sleeve and the pipe passing through it. Sleeves of No. 26 United States standard gauge (0.019 inch) galvanized iron should be installed with approximately 1/4 inch space all around all pipes passing through walls, partitions, and floors above the basement. In cases where a cork covering is used, the sleeves should be of sufficient size to permit installation of the covering with the usual clearance.

T. Floor, Wall and Ceiling Plates Uncovered, exposed pipes passing through floors, finished walls, or finished ceilings should be fitted with floor and ceiling plates not less than 3/32 inch thick. Plates for use on chromium plated pipe should be finished with cast brass, chromium plated. Plates for use on iron pipe should be cast-iron or steel. Floor, wall and ceiling plates should be a one-piece pattern and should have round-head set screws.

Special cast-iron or cast brass plates with deep escutcheons should be provided where it is necessary to cover beads of fittings.

U. Wall Hydrants Hydrants should be installed where indicated on the plans and shall be as specified in Federal Specifications, WW-P-541, paragraph E10L.

V. Street Washers Washers should be installed where shown and shall be as specified in Federal Specification WW-P-541, paragraph E-10K.

W. Water Supply System The water service should be brought to a point 5'0" from the building wall. The exact location should be shown in the plans. A brass, bronze or iron body, bronze trimmed gate valve should be placed on the water supply line at that point. The valve must have a T-handle supplied with a spoon key and a cast-iron extension box and cover. The connections should be covered with asphaltum paint after installation.

Unless otherwise specified, the service line should be controlled by a gate valve located at the lowest accessible point immediately after the service main or branch enters the building. A one inch brass drain valve with a 3/4 inch hose nipple should be installed on the building side of the gate valve to thoroughly drain the entire building distribution system.

The sizes of water pipes should be specified in the plans. All branch lines should be of 3/4" pipe unless otherwise specified. The following table shows the sizes of pipes required for connections to water closets and other fixtures with the maximum number of fixtures which may be connected to any one size of pipe:

Sizes of Water Pipes

No. of Fixtures	Water Closets	Other Fixtures
1 to 2	3/4" - 1-1/2"	3/4"
3 to 8	2"	1"
9 to 12	2-1/2"	1-1/4"
13 to 20	3"	1-1/4"

Other fixtures equal in number to the water closets may be connected to lines serving them without increasing the size of the line. Hot water pipes should be equal in size to the cold water pipes.

Unless otherwise specified, all pipe should be run concealed in finished rooms. The distribution system should be suspended from the basement ceiling. All lines must be pitched and valved to permit complete drainage. The cold water system should be installed with a fall toward the shutoff valve, and the hot water system should grade up to the last riser.

211. Plumbing Instructions

A. Services

Water and gas lines may be laid in individual trenches or parallel to each other in the bottom of the same trench, provided the minimum horizontal space between them is 12 inches. Gas lines must be well tagged with brass tags or painted so they can be distinguished from water lines. Sewers should be laid in trenches that contain no other service pipes. One service line should never be laid on the backfill over another service line or conduit, except at crossings.

B. Trench Excavations

All trench excavations should be made by open cuts. The banks should be kept as nearly vertical as possible and should be properly sheeted and braced. Trenches must be excavated to the lines and grades shown on plans or to an approved depth. Bell holes should be excavated to insure the pipe resting on the bottom of the trench for its entire length. The bottom of each trench must be tamped hard to a uniform and proper grade.

C. Backfilling

All trenches must be backfilled as soon as the pipe lines placed therein have been tested and approved. The material used for backfilling to a depth of not less than one foot over the top of the pipes should be clean earth, sand or rock dust. The space between the pipes and the bottom and sides of the trench should be filled evenly on both sides up to the tops of the pipe. This part of the backfill should be placed by hand and tamped solid with appropriate tools. The pipes should then be covered by hand methods up to one foot above their top and carefully tamped. The remainder of the trench may then be backfilled completely with material free from organic matter, which must be deposited in layers of not more than one foot at a time. Each layer should be thoroughly tamped in place with hammers weighing at least 20 lbs. each. Care should be taken at all times not to injure or disturb the completed lines.

Rock should not be used for backfilling. Water may be used for flooding or puddling the backfill, when approved. Backfilling within two feet of building walls should be uniformly deposited and solidly tamped in a manner that avoids any misalignment or injury to any structure or avoids producing an unequal pressure on it.

D. Drain Tile Lines

Tile drainage lines should be set and held in place by having each tile slightly impressed into a bed of sand not less than one inch thick, which should cover the bottom of the trench and be uniformly leveled or sloped to the proper grade. They should be laid with loose joints, with the intervening space between the tiles being approximately 1/8 inch. The upper half of each joint should be covered with burlap, prior to placing the backfill. The connection of drainage tile lines of other materials should be at manholes, or by cementing one drain tile into the open bell of the terminal piece of connecting lines.

E. Sewer Piping

Sewer lines include all interior downsprouts and all soil, waste and vent lines extended from the building to outside connections. Interior downsprouts should be run to separate drainage fields, tanks, sewers or cesspools when septic tanks are used.

All soil, waste or drain lines, with their connections to the various fixtures, and the vent lines for these fixtures must be installed to insure proper drainage without breaking the seal in the traps of fixtures and to provide adequate removal of all foul air or sewer gas. Wherever possible, the waste line from a lavatory should be discharged into a vertical vent, to wash away any sediment that may collect in the horizontal run of that vent line. All horizontal runs of sewer or waste lines should be run to avoid the formation of pockets. All sanitary lines should terminate with end vents.

All soil and waste lines should be in accordance with the following:

Size of Pipe	Number of water closets whidh may be discharged	
	in a Horizontal Run	in a Vertical Run
4"	1 to 6	1 to 16
5"	7 to 16	17 to 30
6"	17 to 30	31 to 45

Fixtures having $1\frac{1}{2}$" outlets, and totaling not more than twice the number of water closets may be discharged into the lines specified above without increasing the size.

Small fixtures on separate lines should be sized as follows:

Size of Pipe Horizontal or Vertical Runs	No. of 1½" outlets for small fixtures which may be discharged into runs
* 1½"	2
2"	3 to 9
2½"	10 to 20
3"	21 to 36

* 1½" wastes shall be limited to twenty feet in length.

F. Lawn valve installation

Lawn faucets or wall hydrants should be installed at a height not to exceed 30 inches above grade at points designated in the plans.

G. Piping - General

Building service lines are extensions connecting the outside service lines to the fixtures and equipment requiring water or drainage. When the outside service lines have been installed, the final connections to them shall be a part of the work considered as coming under Stage A listed at the beginning of this chapter. When they are not installed, the building service lines should terminate at points approximately 5 feet outside the foundation lines or walls. When so terminated, each line must be capped or plugged and suitably located with a stake or marker protruding above grade. Each section of pipe, fitting special, trap, valve, etc., must be carefully inspected and thoroughly cleaned inside before it is installed. The laying of all pipe will be according to the sizes specified or shown on the drawings.

Any defective pipe, fitting special, trap, valve, etc., or dented brass pipe, that may have been installed must be replaced. All special lengths of pipe shall be cut accurately to measurements established at the site and worked into place without springing or forcing. Cut sections of wrought iron, copper molybdenum iron, copper bearing steel, or brass pipe must be reamed to remove all burrs. All exposed pipe will, when practical, be run parallel to or at right angles with the line of the building or other exposed pipes. Care must be taken to avoid all windows, doors or other openings and electric or other outlets. Structural portions of the building must not be weakened.

All changes in direction should be made with fittings instead of bending the pipe. Reducing fittings must be used exclusively instead of reducing bushings. All piping should be held in alignment with suitable supports or braces. Parallel pipe lines that are insulated must have a clear space of not less than 4 inches between the bare pipes, to facilitate the insulation.

FIXTURE CONNECTIONS

Fixture	Sanitary		Water	
	Cast iron	Steel or Wrought Iron	Cold	Hot
Bath				
a. Continuous flow.	3"	3"	3/4"	3/4"
b. Free standing.	2"	1½"	1/2"	1/2"
c. Tub.	2"	2"	1/2"	1/2"
Drains				
a. Areaway	4"	4"		
b. Floor	2"	2"		
c. Garage	4"	4"		
Fountains				
a. Drinking	2"	1½"	1/2"	
b. Wash	2"	1½"	1/2"	
Lavatories	2"	1½"	1/2"	1/2"
Showers	2"	2"	3/4"	3/4"
Sinks				
a. Comb. & Laundry Tray	2"	1½"	3/4"	3/4"
b. Flat Rm.	2"	1½"	1/2"	1/2"
c. Kitchen	2"	1½"	3/4"	3/4"
d. Laundry trays.	2"	1½"	3/4"	3/4"
e. Service	3"	3"	3/4"	3/4"
f. Wash up	2"	1"	3/4"	3/4"
Urinals				
a. Flush valve.	2"	2"	1"	
b. Tank.	2"	2"	3/4"	
Water Closets				
a. Flush valve	4"	4"	1¼"	
b. Tank	4"	4"	3/4"	

H. Acid Resisting Lines

Acid resisting pipe, fittings and specials will be used for all lines that are to convey fluids which readily attack ferrous and metal pipe.

Joints between sections of acid-resisting pipe and connections between such pipe and fittings and specials, or other lines must be made up in strict accordance with the manufacturers' recommendations.

I. Spacing of Pipe Supports

Pipe supports should be installed to support and hold in alignment all unburied pipe lines. The location of these supports should be:

(a) For bell and spigot pipe - near the bell end of each length of pipe and fitting.

(b) For bolted joint pipe - near the female end of each length of pipe or fitting.

(c) For all other pipe lines - at each change in direction of run exceeding 15 feet in length, with all intermediate supports equally spaced with reference to each other. The maximum spacing of intermediate supports must not exceed 10 feet on centers.

J. Protection of Roughing-in

The installation of all cleanouts, unions, valves, thermometers, gauges or other indicating or recording equipment or specialties requiring frequent reading, adjustment, inspection, removal or replacement, must be conveniently and accessibly located with reference to the finished building.

During the entire time of building construction, each open end of pipe, fitting, special, trap, valve, etc., must be protected by a cap or plug. All pipe must be installed so that it may contract or expand freely without damage to any other work or injury to itself, and to completely eliminate all water hammer.

K. Pipe Coverings

Many different types of pipe covering are used in plumbing practice. Cork or asbestos-sponge felted covering is used for drinking water pipes; air-cell asbestos or 85% magnesia covering is used for hot water pipes. Anti-sweat covering may be used for wastes from drinking fountains, cold water pipes over ceilings, rain leaders over finished ceilings, or other pipes that might condense moisture and allow it to drip where it would cause damage. Pipes exposed in cold places where they are liable to freeze are covered with a frost-proofing material. Carbonate of magnesia is a very poor heat

conductor and is a good material for covering hot water pipes. Carbonate of lime is not a good covering material, although it often masquerades as Carbonate of Magnesium. Carbonate of Magnesium must meet a chemical test of from 80% to 90% magnesia.

212. Plumbing Fixtures

The completed installation of each fixture includes its trimmings and accessories, and stop or control valves in each water control line. Stop or control valves installed in the water supply lines to lavatories, flush tanks, bathtubs and other fixtures must conform to Federal Specification WW-P-541 or be as specified in the plans. Stop or control valves installed in the water supply lines to fixtures for which they are not specified should be located below or back of the fixture they serve, unless the piping installation makes this arrangement impossible. In this case, the control valves should be installed in the branch lines supplying these fixtures. In each instance they must be accessibly located with reference to the finished building.

The waste from each fixture should flow through a "P" or "S" trap so arranged that the discharge from the fixture will flow only through its own trap. Connections between the earthenware of any fixture and the flange on the soil pipe must be made absolutely water and gas tight, with a one-piece special mounted asbestos gasket properly saturated to prevent rotting or drying. Rubber gaskets or putty should not be allowed. No earthenware fixture should be set in place until its flange has been examined and approved.

Unless otherwise specified, the size of the service branch lines extended for connection into each fixture, waste or supply lines should be as specified in the table on Page 371. Reducing fittings are used where these service branch lines and fixtures, waste or supply lines are not of the same size.

Federal Specifications WW-P-541 dated August, 1933, and Amendment dated August 1936 describe the fixtures which should be used, and set up definite rules for their installation. Each separate item is fully described and illustrated.

213. Tests of Plumbing and Drainage Systems

The entire system of supply, soil, waste, drain and vent piping must be tested with water or air, as hereinafter described. All pipes must be tight before the connection is made to the exterior sewer, the trenches backfilled, the piping covered, or the fixtures connected.

Tests must be made with water, except where there is danger from freezing, when the test must be made with air. Wooden plugs should not be used when making the tests. The connections between the building and the city sewer and the drainage system below the basement floor must be tested separately.

A. Water Tests

The connection from the building to the exterior sewer and to the drainage system below the basement floor are each filled with water to the top of a vertical section of pipe 10 feet high. This vertical pipe should be temporarily connected to the highest point on the lines to be tested. The water should be allowed to stand at least 20 minutes for inspection. If the lines prove tight, the water may be drawn off and a connection made with the exterior sewer, and the trenches backfilled.

The soil, waste, drain and vent piping, above the basement floor line must have the openings plugged where necessary and the piping system filled with water to the top of the vent pipes. The water should be allowed to stand at least 30 minutes for inspection. If the lines prove tight, the water may be drawn off and the fixtures connected. Each vertical stack with its branch waste and vent pipes may be tested separately by inserting plugs in the cleanouts at the base of verticals instead of filling the entire system with water.

B. Air Tests

A pressure of not less than 10 pounds per square inch, equal to 20 inches of mercury, must be supplied with a force pump. The pressure must be maintained at least 15 minutes without leakage. A mercury column gauge should be used in making air tests. Pipes must be plugged as indicated for water tests.

C. Smoke Tests

After all fixtures have been permanently connected, a smoke test must be applied to the sanitary system. The entire system must be proved tight to the satisfaction of a responsible Forest Officer, when it is filled with smoke under a pressure equal to 1 inch of water. The smoke must not be produced by chemical mixtures.

D. Test of Water Supply System

At the completion of the work, except for the application of the non-conducting coverings, the water supply system must be tested to a hydrostatic pressure of 100 pounds to the square inch.

Any water piping run in chases in walls, furred spaces or in any way concealed by structural work must be tested to the above pressure and proved tight before the pipes are concealed.

E. Test of Gas Piping

The gas piping must be tested to an air pressure of 50 pounds per square inch applied with a force pump and maintained for 15 minutes without leakage.

References:

Department of Interior - Office of Indian Affairs, Specifications, F.P. 555 Ind.

Federal Specifications for Materials WW-P-541

General Specifications for Buildings - Soil Conservation Service - W. E. Groben

National Association of Master Plumbers

CHAPTER XXIV - HARDWARE

214. Builders Hardware.

This section of the handbook is intended to supplement Forest Service plans to the extent that some general information be made available to the man on the ground as well as to those planning Forest Service buildings or structures. Building hardware should be chosen for utility and service, as well as appearance, and the various items should be of harmonious style, pattern and finish.

The style of hardware will usually be specified in the plans. As a guide in selecting proper items for various Forest Service building needs, reference is made to the following Federal Specifications:

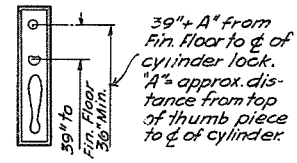
FF-H-106 - Builders Hardware, Locks & Lock-Trim
FF-H-111 - Builders Hardware, Shelf & Miscellaneous
FF-H-116 - Builders Hardware, Hinges

When it is necessary to use special items which are not covered by Federal Specifications, the items of reputable manufacture which fill the need may be specified as examples of the kind, size or quality desired. In such specifications, the manufacturer's name, the catalog and style number and the size may be used. Equal items of other manufacture may be accepted where a construction other than that illustrated or described shall constitute a full commercial equivalent of the one shown in the specification or order.

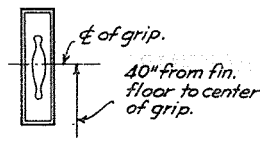
All hardware items should be properly boxed so that they can be protected from injury when they are received. Each box should be properly labelled so that the contents can be identified when the hardware is to be installed.

Standard practice and experience has provided considerable information about placing or installing hardware. This experience has brought about better construction. Information and instructions regarding the location and installation of hardware will be found in the illustrations shown on Pages 378, 379, 380, and 381.

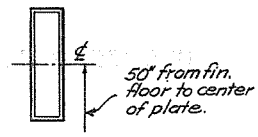
All workmen are urged to make sure that mortises are truly and accurately laid out and cut, and that they are free from chips, shavings or dirt before the hardware is placed in position. They should be careful not to mar the wood trim or finish, or mar the hardware finish during placing. All hardware should be checked to make certain that all parts are complete, that all screws or bolts are in place and that it is assembled correctly and operates properly when installed. When face, push plates, or other parts of hardware are removed during painting and finishing they should be carefully packed and taken care of until they are re-installed. Door knobs should be wrapped with a cloth of soft finish as soon as they are installed and should remain so protected until the job is complete and ready for use.



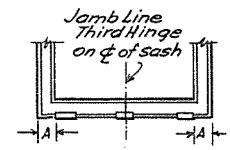
ENTRANCE OR STORE DOOR LOCK



DOOR PULL

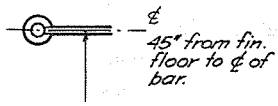


PUSH PLATE

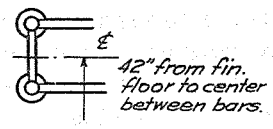


A = 3" when stiles are 3" or less in width.
A = Width of stile when width of stile is greater than 3".

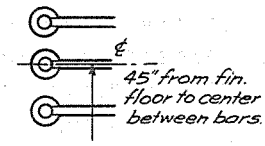
HINGES
Sash hinged at top or bottom jamb line.



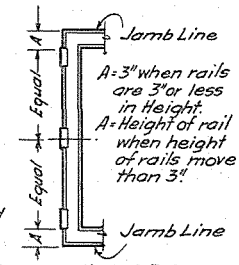
PUSH BAR



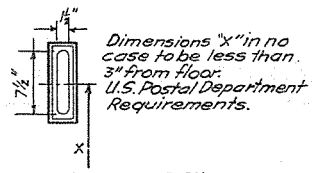
PUSH & GUARD BARS
with or without grab bars.



PUSH & GUARD BARS

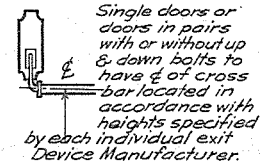


HINGES

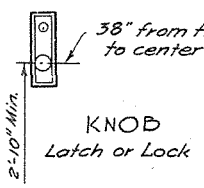


VERTICAL TYPE LETTER BOX
Place in Hinge Stile

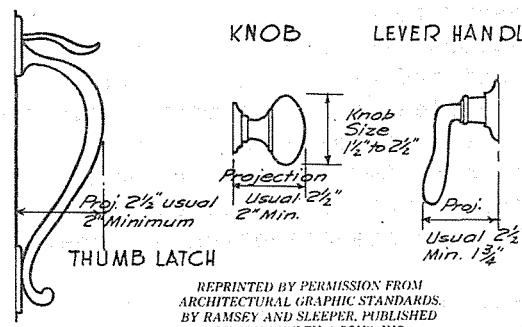
HORIZONTAL TYPE LETTER BOX
Place in Cross Rail


Single doors or doors in pairs with or without up & down bolts to have ℄ of cross bar located in accordance with heights specified by each individual exit Device Manufacturer.
℄

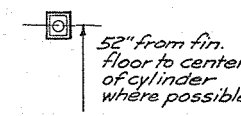
PANIC OR EXIT DEVICES



KNOB
Latch or Lock



THUMB LATCH



CYLINDER
Dead Lock

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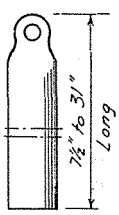
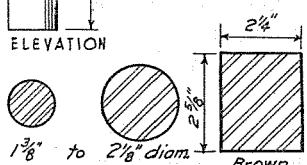
CLEARANCE FOR KNOBS, LEVER HANDLES & THUMB LATCHES
The above projections govern Rebate widths for storm doors, screen doors, screens, louvre doors, etc.

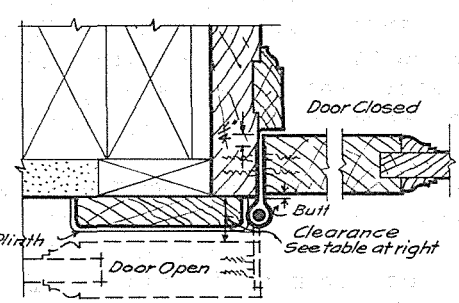


ELEVATION



PLANS

SASH WEIGHTS
Pocket for sash weights generally 2¼" for residential work.



CLEARANCE OF BUTTS

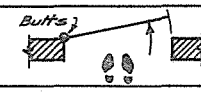
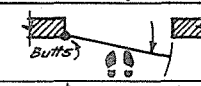
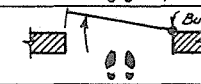
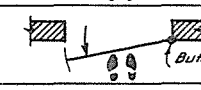
CLEARANCE OF STOCK SIZE BUTTS

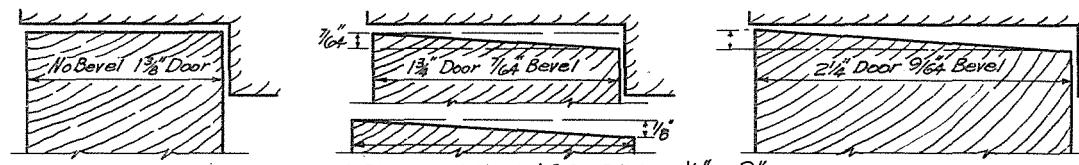
Thickness of door	Size of Butt	Maximum Clearance
1⅜"	3" x 3" 3½" x 3½" 4" x 4"	¾" ⅞" 1⅝"
1¾"	4" x 4" 4½" x 4½" 5" x 5"	1" 1⅜" 2"
2"	4½" x 4½" 5" x 5" 6" x 6"	1½" 1¾" 2¾"
2¼"	5" x 5" 6" x 6" 6" x 7" 6" x 8"	1¼" 2¼" 3¼" 4¼"

HARDWARE

RULE FOR HAND OF LOCKS

Stand on side of door from which security is desired, i.e. outside.

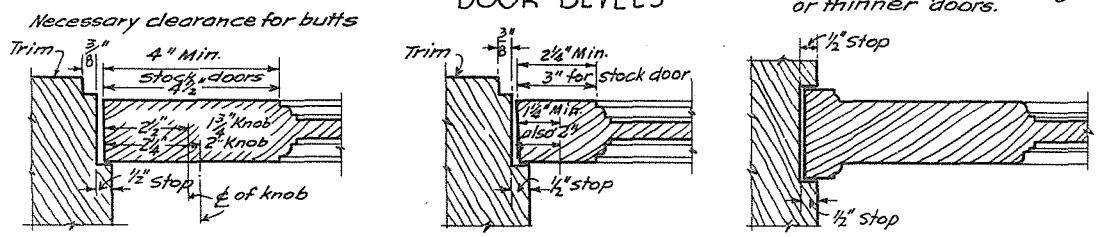
IF BUTTS ARE ON LEFT SIDE & DOOR SWINGS AWAY FROM YOU		LEFT HAND REGULAR
IF BUTTS ARE ON LEFT SIDE & DOOR SWINGS TOWARD YOU		LEFT HAND REVERSE
IF BUTTS ARE ON RIGHT SIDE & DOOR SWINGS AWAY FROM YOU		RIGHT HAND REGULAR
IF BUTTS ARE ON RIGHT SIDE & DOOR SWINGS TOWARD YOU		RIGHT HAND REVERSE



BASIS OF STANDARD BEVEL 1/8" IN 2"

DOOR BEVELS

Bevels not required on 1⅜" or thinner doors.

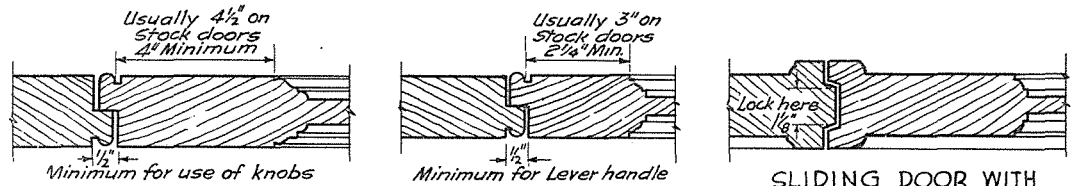


DOOR WITH KNOB
Using bit key or cylinder lock these doors shown with bevel.

DOOR WITH LEVER HANDLE
Using bit key or cylinder lock same dimensions hold for thinner doors

SLIDING DOOR

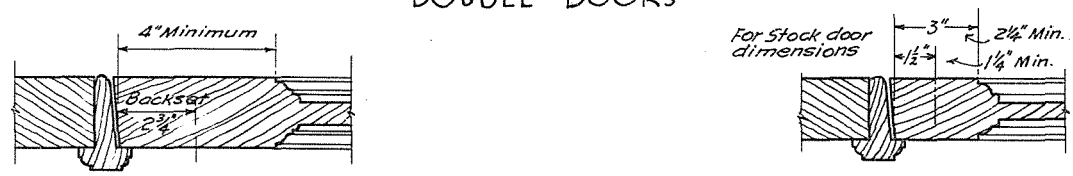
SINGLE DOORS



RABBETED MEETING STILE
Cylinder or bit key lock.

SLIDING DOOR WITH ASTRAGAL

DOUBLE DOORS



FOR KNOB
BEVELLED FOR CYLINDER LOCK

FOR LEVER HANDLES

DOUBLE DOORS WITH FLAT ASTRAGALS

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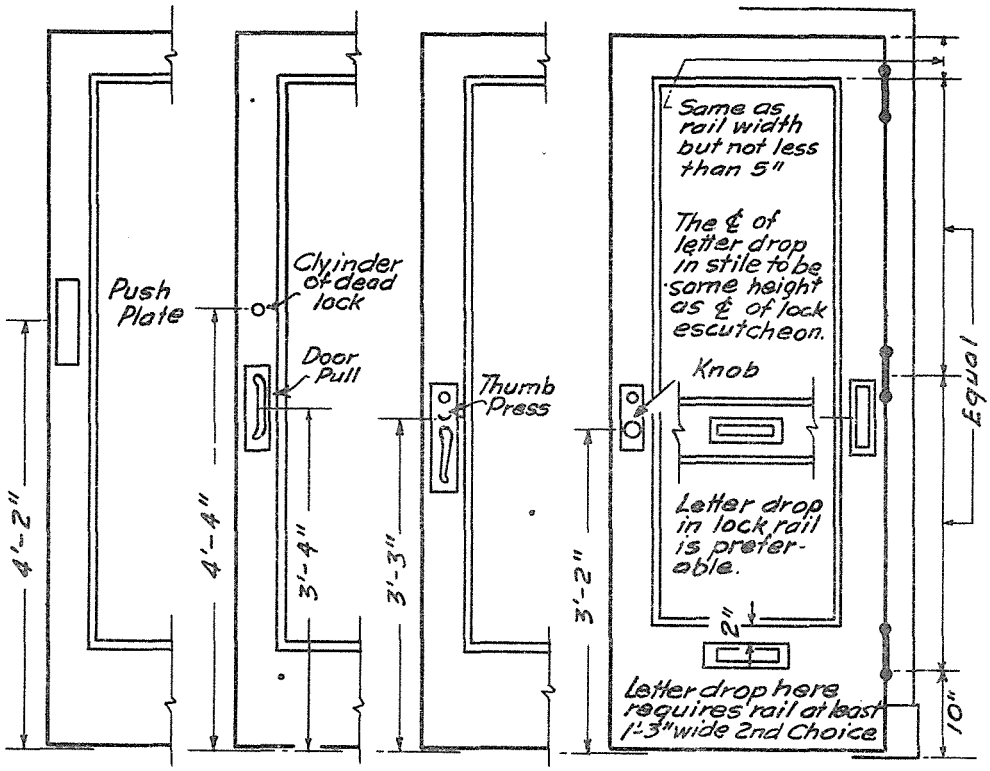
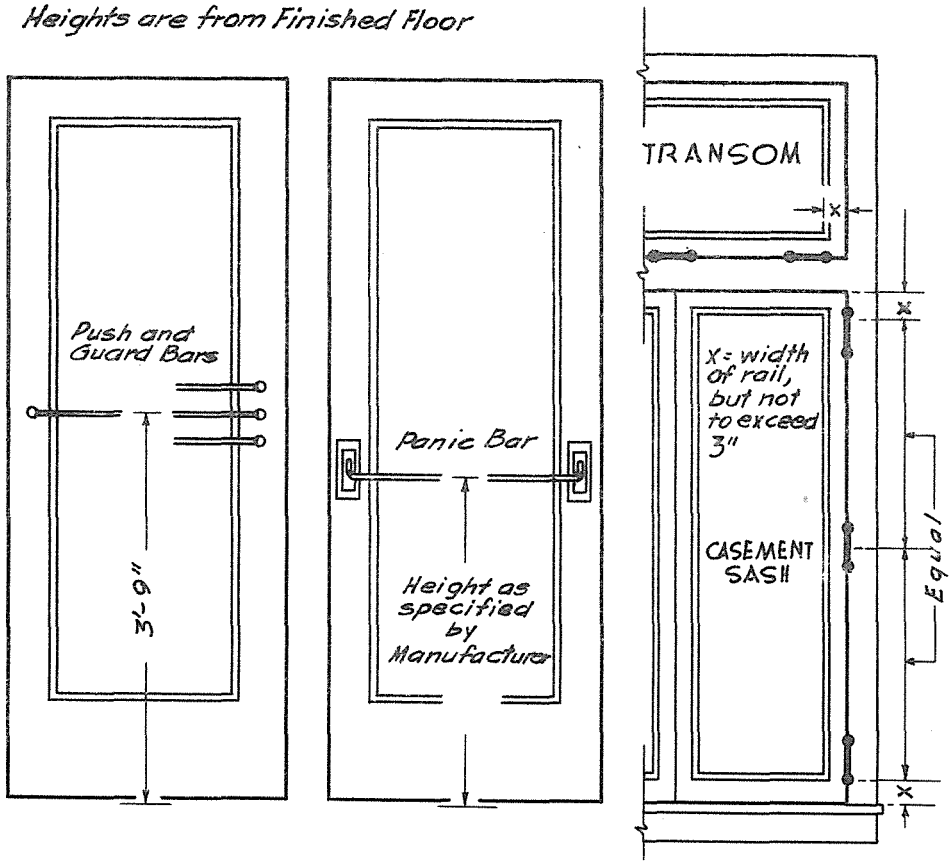
DOOR HARDWARE

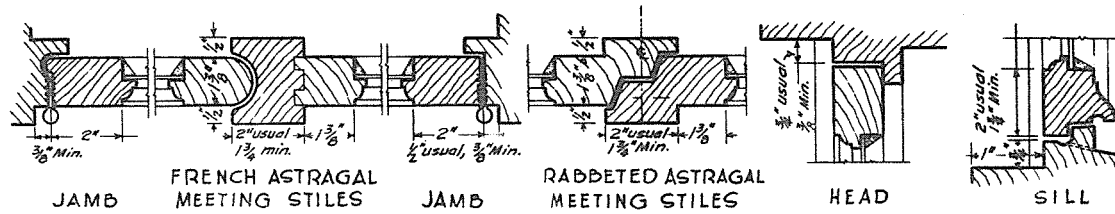


Heights are from Finished Floor

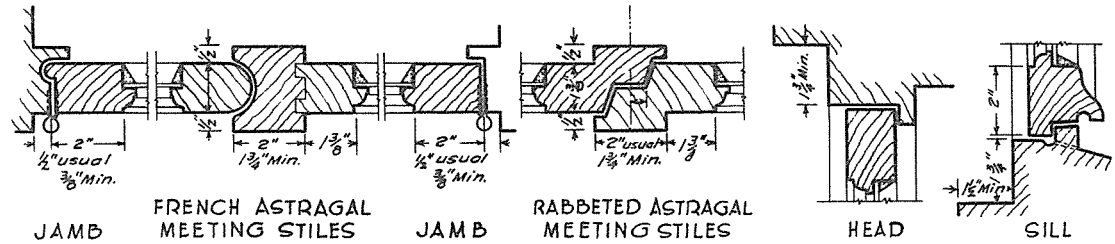


COURTESY OF DON GRAF

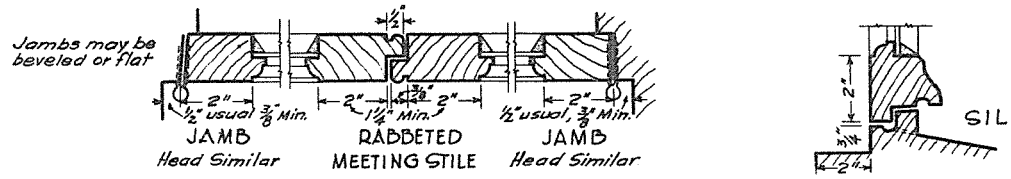
LOCATION OF DOOR HARDWARE



FOR USE WITH CREMONE BOLT & ADJUSTER



FOR USE WITH ESPAGNOLETTE BOLT AND ADJUSTERS



FOR USE WITH RIM or MORTISE CASEMENT FASTENER or TURNBUCKLE & ADJUSTER

For use with sash not over 4'-0" High

CASEMENTS OPENING IN

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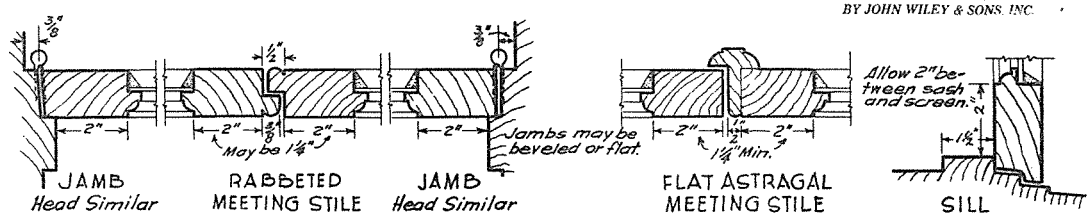
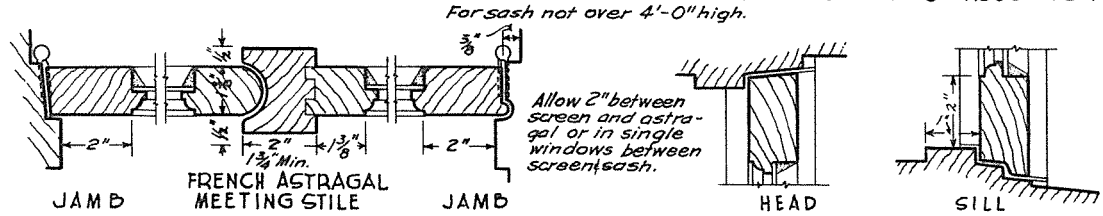


FOR USE WITH RIM or MORTISE CASEMENT FASTENER or TURNBUCKLE & ADJUSTER

For sash not over 4'-0" high.



FOR USE WITH CREMONE BOLT & ADJUSTER

CASEMENTS OPENING OUT

WINDOW HARDWARE

When special hardware is to be installed, the hardware manufacturers' instructions should be carefully followed. Workmen first study these instructions before making any move toward making the hardware installation and should then proceed to carefully carry them out.

215. Bridge Hardware.

Bridge hardware such as steel truss rods and structural shapes, must conform to Federal Specification QQ-S-711, steel, structural for bridges, Class A, non-copper.

All steel castings must conform to Federal Specification QQ-S-681.

Holes for dowels, bolts, and rods, should be bored with the following diameter:

Type of Bolt or Rod	Diameter on Hole
Round Dowels or Drift Bolts	1/8" less than rod
Square Dowels or Drift Bolts	Equal to least dimension of rod
Machine Bolts	Same as bolt
Rods	1/16" greater than rod

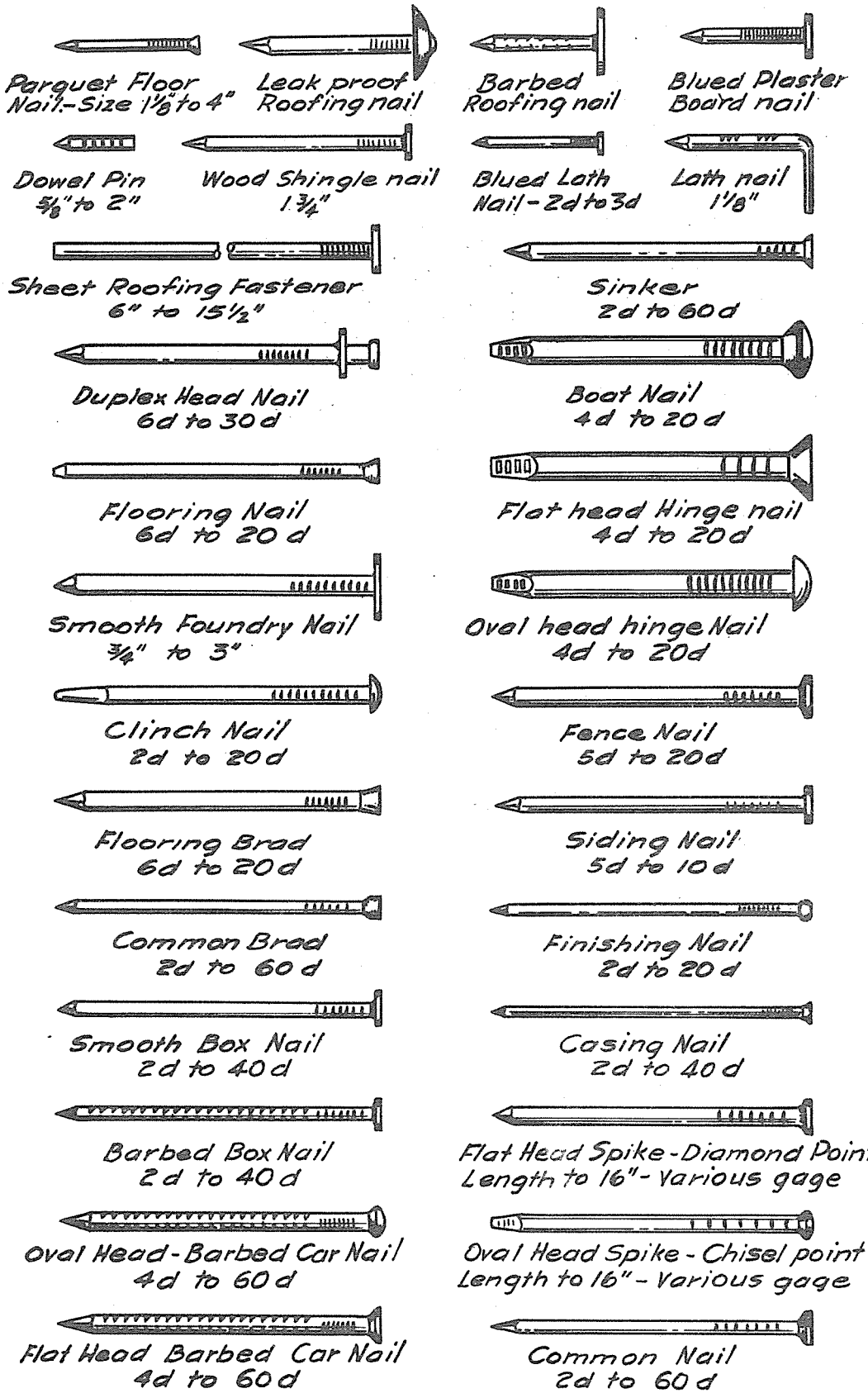
Cast iron or malleable washers should be used under all bolt heads or nuts which would otherwise come in contact with the wood. Cast iron washers should have a thickness equal to the diameter of the bolt and a diameter of 4 times the thickness. Malleable washers should have a thickness equal to half the diameter of the bolt and a diameter or side size equal to 4 times the diameter of the bolt.

Masonry plates should be set level in exact position with a full and even bearing upon the bridge seat. When indicated on the plans, the plates should be set on red lead and canvas in the following manner:

> After the truss or girder is erected, it should be jacked off the masonry bearing plate. The bearing area under the masonry plate should then be swabbed with red lead paint and covered with three layers of 12 oz. to 14 oz. duck. Each layer should be swabbed in turn with red lead. The masonry bearing plates and the superstructure shoes or end bearings should then be let down into position while the red lead is still plastic.

Anchor bolts should be accurately placed and the nuts on anchor bolts at the expansion end must be adjusted to permit free expansion and contraction.

Drift bolts are driven into holes 1/8" less than the bolt diameter. The resistance to withdrawal of round drift bolts, inserted perpendicular to the grain, is intimately related to the density or the specific gravity of the wood. The character of the work must indicate the factor of safety to be used.


Parquet Floor Nail - Size 1⅛ to 4"
Leak proof Roofing nail
Barbed Roofing nail
Blued Plaster Board nail
Dowel Pin ⅝" to 2"
Wood Shingle nail 1¾"
Blued Lath Nail - 2d to 3d
Lath nail 1⅛"
Sheet Roofing Fastener 6" to 15½"
Sinker 2d to 60d
Duplex Head Nail 6d to 30d
Boat Nail 4d to 20d
Flooring Nail 6d to 20d
Flat head Hinge nail 4d to 20d
Smooth Foundry Nail ¾" to 3"
Oval head hinge Nail 4d to 20d
Clinch Nail 2d to 20d
Fence Nail 5d to 20d
Flooring Brad 6d to 20d
Siding Nail 5d to 10d
Common Brad 2d to 60d
Finishing Nail 2d to 20d
Smooth Box Nail 2d to 40d
Casing Nail 2d to 40d
Barbed Box Nail 2d to 40d
Flat Head Spike - Diamond Point Length to 16" - Various gage
Oval Head - Barbed Car Nail 4d to 60d
Oval Head Spike - Chisel point Length to 16" - Various gage
Flat Head Barbed Car Nail 4d to 60d
Common Nail 2d to 60d

COURTESY OF DON GRAF

NAILS

QUANTITY OF NAILS REQUIRED FOR 100 SQUARE FEET OF LAMINATED FLOORS, USING 2 INCH FLOORING

Distance Spikes are Spaced Apart

Size Spikes	12 inches No.	Lbs.	16 inches No.	Lbs.	20 inches No.	Lbs.	24 inches No.	Lbs.	30 inches No.	Lbs.
16d	740	15	600	12¼	518	10½	450	9¼	370	7½
20d	740	24	600	19¼	518	16¾	450	14½	370	12
30d	740	31	600	25	518	21½	450	18¾	370	15½
40d	740	41	600	33¼	518	28¾	450	25	370	20½
50d	740	53	600	43	518	37	450	32	370	26½
60d	740	67	600	55	518	47	450	41	370	33¾

QUANTITY OF NAILS REQUIRED FOR 100 SQUARE FEET OF LAMINATED FLOORS, USING 3 INCH FLOORING

Distance Spikes are Spaced Apart

Size Spikes	12 inches No.	Lbs.	16 inches No.	Lbs.	20 inches No.	Lbs.	24 inches No.	Lbs.	30 inches No.	Lbs.
16d	440	9	352	7¼	308	6¼	264	5½	220	4½
20d	440	14¼	352	11½	308	10	264	8½	220	7
30d	440	18½	352	14¾	308	12¾	264	11	220	9¼
40d	440	24½	352	19½	308	17	264	14¾	220	12¼
50d	440	31½	352	25¼	308	22	264	18¾	220	15¾
60d	440	40	352	32	308	28	264	24	220	20

QUANTITY OF NAILS REQUIRED FOR 100 SQUARE FEET OF LAMINATED FLOORS, USING 4 INCH FLOORING

Distance Spikes are Spaced Apart

Size Spikes	12 inches No.	Lbs.	16 inches No.	Lbs.	20 inches No.	Lbs.	24 inches No.	Lbs.	30 inches No.	Lbs.
16d	320	6½	256	5¼	224	4½	192	4	160	3¼
20d	320	10½	256	8¼	224	7¼	192	6¼	160	5¼
30d	320	13½	256	10¾	224	9½	192	8	160	6¾
40d	320	17¾	256	14¼	224	12½	192	10¾	160	9
50d	320	23	256	18¼	224	16	192	13¾	160	11½
60d	320	29	256	23¼	224	20½	192	17½	160	14½

WIRE NAILS - KINDS AND QUANTITIES REQUIRED

Length, inches	AS & W steel wire gauge	Approx. number to pounds	Nailings	Sizes and kinds of material	Trade Names	Pounds per 1,000 feet b.m. on center as follows:				
						12 in.	16 in.	20 in.	36 in.	48 in.
2½	10¼	106	2	1 x 4 I. Used square	8d common	60	48	37	23	20
2½	10¼	106	2	1 x 6 edge, as platforms,	8d common	40	32	25	16	13
2½	10¼	106	2	1 x 8 floors, sheathing,	8d common	31	27	20	12	10
2½	10¼	106	2	1 x 10 or shiplap.	8d common	25	20	16	10	8
2½	10¼	106	3	1 x 12	8d common	31	24	20	12	10
4	6	31	2	2 x 4 II. When used D.& M.	20d common	105	80	65	60	33
4	6	31	2	2 x 6 blind nailed, only	20d common	70	54	43	27	22
4	6	31	2	2 x 8 one-half quantity	20d common	53	40	53	21	17
4	6	31	3	2 x 10 named required.	20d common	60	50	40	25	20
4	6	31	3	2 x 12	20d common	52	41	33	21	17
6	2	11	2	3 x 4	60d common	197	150	122	76	61
6	2	11	2	3 x 6	60d common	131	97	82	52	42
6	2	11	2	3 x 8	60d common	100	76	61	38	34
6	2	11	3	3 x 10	60d common	178	137	110	70	55
6	2	11	3	3 x 12	60d common	145	115	92	58	46
2½	12½	189	2	Base, per 100 feet lining	8d finish	..	1			
2½	10¼	106	2	Byrket lath	8d common	..	48			
2½	12½	189	1	Ceiling, 3/4 x 4	8d finish	18	14			
2	13	309	1	Ceiling, 1/2 and 5/8	6d finish	11	8			
2⅛	12½	189	2	Finish, 7/8	8d finish	25	12			
3	11½	121	2	Finish, 1-1/8	10d finish	12	10			
2½	10	99	1	Flooring, 1 x 3	8d floor brads	42	32			
2½	10	99	1	Flooring, 1 x 4	8d floor brads	32	26			
2½	10	99	1	Flooring, 1 x 6	8d floor brads	22	18			
4	6	31	)	Framing, 2 x 4 to 2 x 16 (	20d common	20	16	14		
3½	8	49	)	requires 3 or more sizes (	16d common	10	10	8		
3	9	69	)	and vary greatly (	10d common	8	6	5		
6	2	11	)	Framing, 3 x 4 to 3 x 14 (	60d common	30	25	20		

WIRE NAILS - KINDS AND QUANTITIES REQUIRED
(continued)

Length, inches	AS & W steel wire gauge	Approx. number to pounds	Nailings	Sizes and kinds of material	Trade Names	Pounds per 1,000 feet b.m. on center as follows:				
						12 in.	16 in.	20 in.	36 in.	48 in.
2½	11½	145	2	Siding, drop 1 x 4	8d casing	45	35			
2½	11½	145	2	Siding, drop 1 x 6	8d casing	30	25			
2½	11½	145	2	Siding, drop 1 x 8	8d casing	23	18			
2	13	309	1	Siding, bevel, 1/2 x 4	6d finish	23	18			
2	13	309	1	Siding, bevel, 1/2 x 6	6d finish	15	13			
2	13	309	1	Siding, bevel, 1/2 x 8	6d finish	12	10			
				Casing, per opening	6d & 8d casing	About 1/2 pound per side				
1¼	14	568	12 in.c-c	Flooring, 3/8 x 2	3d brads	About 10 pounds per 1,000 square feet				
1-1/8	15	778	16 in.c-c	Lath, 48 inches	3d fine	6 pounds per 1,000 pieces				
7/8	12	469	2 in.c-c	Ready roofing	Barbed roofing	3/4 pound to the square				
7/8	12	469	1 in.c-c	Ready roofing	Barbed roofing	1-1/2 pounds to the square				
7/8	12	180	2 in.c-c	Ready roofing (5/8 heads)	Amer. felt "	1-1/2 pounds to the square				
7/8	12	180	1 in.c-c	Ready roofing (5/8 heads)	Amer. felt "	3 pounds to the square				
1¼	13	429	.....	Shingles	3d shingle	4½ lbs.; about 2 nails to each 4 inches				
1½	12	274	.....	Shingles	4d shingle	7½ lbs.; about 2 nails to each 4 inches				
7/8	12	180	4	Shingles	Am. felt roofing	12 lbs.; 5/8 in. heads; 4 nails to shingle.				
7/8	12	469	4	Shingles	Barbed roofing	4½ lbs.; 5/8 in. heads; 4 nails to shingle.				
1	16	1,150	2 in.c-c	Wall board, around entire edge	Second Barbed Berry, flat head	5 lbs., 5/8 in. heads, per 1,000 square feet.				
1	15½	1,010	3 in. c-c	Wall board, intermediate nailings	Second casing or floor brad	2½ lbs., 5/8 in. heads; per 1,000 square feet.				

NAIL SIZES AND WEIGHTS

Common nails and brads*				Casing-nails**		Finishing-nails***	
Sizes	Length, in.	AS & W gauge	Number to lb.	AS & W gauge	Number to lb.	AS & W gauge	Number to lb.
2d	1	15	876	15½	1 010	16½	1 351
3d	1¼	14	568	14½	635	15½	807
4d	1½	12½	316	14	473	15	584
5d	1¾	12½	271	14	406	15	500
6d	2	11½	181	12½	236	13	309
7d	2¼	11½	161	12½	210	13	238
8d	2½	10¼	106	11½	145	12½	189
9d	2¾	10¼	96	11½	132	12½	172
10d	3	9	69	10½	94	11½	121
12d	3¼	9	63	10½	87	11½	113
16d	3½	8	49	10	71	11	90
20d	4	6	31	9	52	10	62
30d	4½	5	24	9	46	.....	.....
40d	5	4	18	8	35	.....	.....
50d	5½	3	14				

Spikes			
Sizes	Length, in.	AS & W gauge	Number to lb.
10d	3	6	41
12d	3¼	6	38
16d	3½	5	30
20d	4	4	23
30d	4½	3	17
40d	5	2	13
50d	5½	1	10
60d	6	1	9
7"	7	5/16	7
8"	8	3/8"	4
9"	9	3/8"	3½
10"	10	3/8"	3
12"	12	3/8"	2½

Shingle-nails			
Size	Length, in.	AS & W gauge	Number to lb.
3d	1¼	13	429
3½d	1-3/8	12½	345
4d	1½	12	274
5d	1¾	12	235
6d	2	12	204
7d	2¼	11	139
8d	2½	11	125
9d	2¾	11	114
10d	3	10	83

Fine nails			
2d	1	16½	1 351
3d	1-1/8	15	778
4d	1½	14	473
2d extra fine	1	17	1 560
3d extra fine	1-1/8	16	1 015

* Common brads differ from common nails only in the head and point.
** Lengths are the same as common nails for corresponding size.
*** Spikes are made with chisel-points and diamond points; also with convex heads and flat heads.

NAIL SIZES AND WEIGHTS
(Continued)

Clinch-nails				Fence-nails*		Slating-nails*	
Sizes	Length, in.	AS & W gauge	Number to lb.	AS & W gauge	Number to lb.	AS & W gauge	Number to lb.
2d	1	14	710	No. 5 smallest size		12	411
3d	1¼	13	429			10½	225
4d	1½	12	274			10½	187
5d	1¾	12	235	10	142	10	142
6d	2	11	157	10	124	9	103
7d	2¼	11	139	9	92		
8d	2½	10	99	9	82	Barbed Roofing-nails**	
9d	2¾	10	90	8	62		
10d	3	9	69	7	50	3/4"xNo.13	714
12d	3¼	9	62	6	40	7/8"xNo.12	469
16d	3½	8	49	5	30	1" xNo.12	411
20d	4	7	37	4	23	1-1/8"xNo.12	365
						1-1/4"xNo.11	251

* Length same as clinch-nails of corresponding size.
**Roofing-nails are designated by the length, not by PENNY. These nails are made in lengths up to 2 inches.

WIRE-TACKS

Title, ounce	Length, in.	Number per lb.	Title, ounce	Length, in.	Number per lb.	Title, ounce	Length, in.	Number per lb.
1	1/8	16 000	4	7/16	4 000	14	13/16	1 143
1½	3/16	10 666	6	9/16	2 666	16	7/8	1 000
2	1/4	8 000	8	5/8	2 000	18	15/16	888
2½	5/16	6 400	10	11/16	1 600	20	1	800
3	3/8	5 333	12	3/4	1 333	22	1-1/16	727
....	....	.....	...	.....	.....	24	1-1/8	666

Wire carpet-tacks are made polished, blued, tinned, or coppered; there are also upholsterers' and bill-posters' or railroad tacks.

Oval and Round head screws come in same sizes.

FLAT HEAD WOOD SCREWS

216. Miscellaneous Hardware.

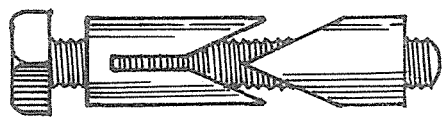
A. Nails.

Most types of nails are illustrated on Page 383. Other information regarding names, lengths, gauges, weights, etc., will be found in the tables on Pages 384 to 388 inclusive.

The "penny" system of designating nails originated in England. Two explanations are offered as to how this curious designation came about. One is that the 6 penny, 4 penny, 10 penny, etc., nails, derived their names from the fact that 100 cost 6 pence, 4 pence, etc. The other explanation, which is more probable, is that 1,000 10 penny nails, for instance, weighed 10 lbs. The ancient, as well as the modern, abbreviation for penny is "d", being the first letter of the Roman coin Denarius. The same abbreviation was used in early history for the English pound in weight.

B. Expansion Bolts.

Expansion bolts are used for bolting wood or iron to concrete that is already set. A hole is drilled in the concrete and the expansion nut is placed in it. When the bolt is screwed up tight, the nut expands and is bound firmly in the concrete. The average safe working stress of expansion nuts may be assumed as 50 lbs. per square inch in concrete and 100 lbs. per sq. in. in lead. The following illustration shows a typical expansion bolt:



EXPANSION BOLT

C. Wood Screws.

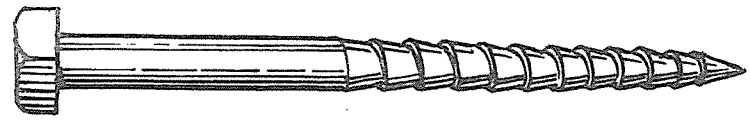
Wood screws are commonly made of steel or brass with flat, round, or oval heads. They come in various lengths, ranging from 1/4" to 5", and each length is made in a number of gauges or diameters.

The sizes of screws are designated by both length and number. The number denotes the diameter and is based on the American Screw Gauge. For example a 1 inch #12 screw is 1" long and 0.2158 inches in diameter. Illustrations of various sizes of screws are shown on Page 389. When screws are ordered, the length, number of the gauge, and the material and finish should be designated. Wood screws are usually sold by the gross.

D. Lag Screws.

Lag screws are used where great strength is required. The most common use in Forest Service work is for heavy framing and for attaching iron work to wood. Lag screws are commonly made in two styles, which are illustrated on Page 391. The gimlet point lag screw is made

with 1/4" to 5/16" diameter, and in lengths from 1-1/2" to 4". Fetter drive lag screws are made with 3/8", 1/2", 5/8", and 3/4" diameter and in lengths ranging from 2-1/4" to 8" depending upon the diameter.



FETTER DRIVE LAG SCREW

GIMLET POINT LAG SCREW

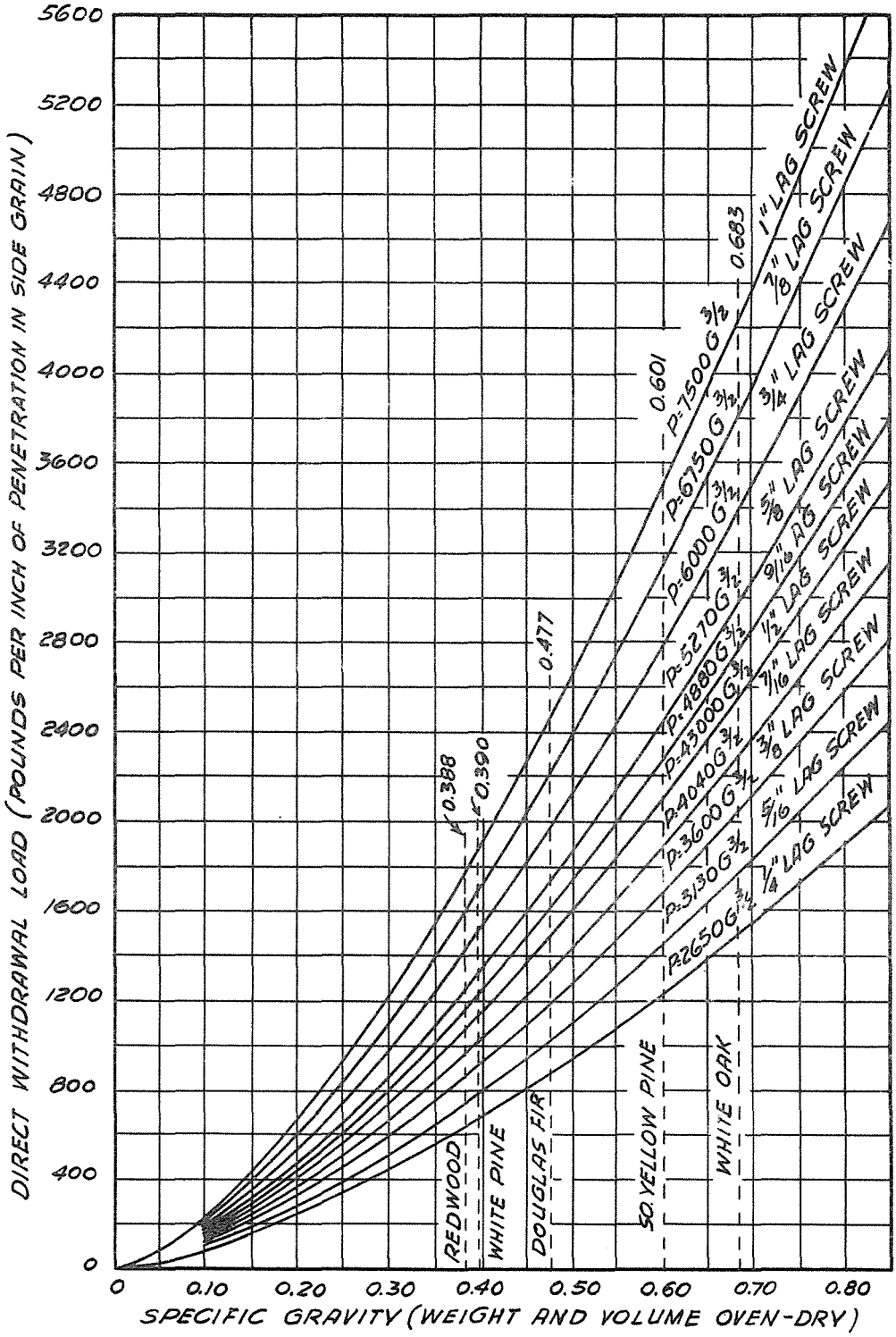
(a) Installation.

Lag screws should be installed by first boring a hole slightly larger in diameter than the unthreaded portion of the shank. The depth of this hole should be equal to the length of the unthreaded shank. A second hole should be bored in the bottom of the first hole with the diameter slightly less than the threaded portion of the shank and with the depth approximately 1/2 the length of the threaded portion. The lag screw is then inserted in the hole and drawn up tight with a wrench.

(b) Direct Withdrawal from Side Grain.

The curves on Page 392 show the ultimate direct withdrawal loads per inch of penetration of the threaded portion of lag screws of different shank diameters. By means of this set of curves, the ultimate loads for any species may be determined from its specific gravity without material error. Horizontally opposite the intersections of any vertical line representing the specific gravity of a given species, with the curve representing the shank diameter of the screw, will be found the ultimate withdrawal load per inch of penetration. One-fifth of this load is the recommended safe load per inch of penetration for a given size screw in timber of a given specific gravity. A factor of 5 instead of the customary 3-1/2 or 4 is used here because the moisture content of the wood was about 10 percent, which is much lower than that of most timbers in service. For convenience in applying the curves, the table on Page 393 gives the values for the specific gravity of the more important structural species.

The resistance of a lag screw in an end grain surface is about three-fourths of that given for side grain.



RELATION BETWEEN WITHDRAWAL LOADS OF LAG SCREWS AND SPECIFIC GRAVITY OF WOOD

SPECIFIC GRAVITY OF COMMERCIALLY IMPORTANT SPECIES OF WOOD, BASED ON OVEN-DRY WEIGHT AND VOLUME

Species	Specific gravity	Species	Specific gravity
HARDWOODS		HARDWOODS (continued)	
Alder, red	0.43	Oak	0.68
Ash, black	.53	Poplar, yellow	.43
Ash, white	.64	Sycamore	.54
Aspen	.40	Walnut, black	.56
Basswood	.40	Willow, black	.41
Birch, yellow	.66		
Buckeye, yellow	.38	CONIFERS	
Butternut	.40		
Cherry, black	.53	Cedar, Port Orford	.44
Chestnut	.45	Cedar, western red	.34
Cottonwood	.43	Cedar, northern white	.32
Cucumber, magnolia	.52	Cypress, southern	.48
Elm, American	.55	Douglas fir	.51
Elm, rock	.66	Fir, commercial white	.42
Gum, black	.55	Hemlock, eastern	.43
Gum, red	.53	Hemlock, western	.44
Gum, tupelo	.52	Larch, western	.59
Hackberry	.56	Pine, ponderosa	.42
Hickory	.72	Pine, northern white	.37
Locust, black	.71	Pine, southern yellow	.58
Madrone	.69	Redwood	.39
Magnolia, evergreen	.53	Spruce	.39
Maple, hard	.68	Tamarack	.56
Maple, soft	.51		

EQUATIONS FOR COMPUTING SAFE LATERAL LOADS FOR LAG SCREWS DRIVEN INTO SIDE GRAIN

Group	Species of wood	Equation
1	Cedar, northern and southern white Fir, balsam and commercial white Hemlock, eastern Pine, ponderosa, sugar, northern white, and western white Spruce, Engelmann, red, Sitka, and white	$1500D^2$
2	Aspen and largetooth aspen Basswood Cedar, Alaska, Port Orford, and western red Chestnut Cottonwood, black and eastern Cypress, southern Douglas fir (Rocky Mountain type) Hemlock, western Pine, Norway Redwood Tamarack Yellow Poplar	$1700D^2$
3	Ash, black Birch, paper Douglas fir Elm, American and slippery Gum, black, red, and tupelo Larch, western Maple, (soft) red and silver Pine, southern yellow Sycamore	$1900D^2$
4	Ash, commercial white Beech Birch, sweet and yellow Elm, rock Hickory, true and pecan Maple, black and sugar Oak, commercial red and white	$2200D^2$

(c) Safe Lateral Loads for Lag Screws.

Equations for use in calculating safe loads for lag screws of different sizes used with different species of wood are given in the table on Page 394. The "D" refers to the shank diameter of the screw.

The equations refer to lag screw joints having a cleat thickness 3.5 times the shank diameter of the screw and a depth of penetration of the screw in the main member varying from eleven times this diameter for group 1 woods to seven times for group 4 woods. The values in the table assume that the shank of the screw extends to the surface of contact between the cleat and the block. If the shank fails to extend this far in the cleat the loads may decrease as much as 20 percent. The safe loads also apply to lag screws having a yield point of 45,000 pounds per square inch used with timber at about 15 percent moisture content. When the timber is occasionally wet but quickly dried, the safe loads should be reduced one-fourth. If the wood is damp or wet most of the time they should be reduced one-third. If screws of a different quality of metal are used, adjust the loads by applying as a factor the square root of the ratio of the yield point of the given metal to 45,000.

E. Bolts.

Bol may be secured in diameters up to 6 inches, with heads and nuts made according to U. S. Standard and American Bridge Standard specifications, and with Screw Threads meeting American Standard Free Fit - Class 2. Information regarding bolts may be obtained from the Carnegie "Pocket Companion", the Illinois Steel Company, "Pocket Companion", and other steel handbooks.

In general bolts in wooden trusses are subject to the same kinds of stresses as rivets and pins in steel structures. If the pieces are less than 2" thick and the bolts are drawn up so as to develop frictional resistance between them, the bolts are proportioned to resist the total force in shear and in bearing. If the pieces are more than 2" thick, the bending is taken into account and the bolts must be investigated for stresses in shear, in bearing, and in bending. The shear is assumed to be uniformly distributed over the cross section of the bolt, and the bearing area is the area of the projection of the bolt on the timber, which is equal to the diameter of the bolt multiplied by the length of the bolt in contact. The bearing strength is given as a property of the bolt but its value depends upon the crushing strength of the timber. The bending movement on the bolt is found in the same manner as for pins in steel trusses.

References:

Wood Handbook, Forest Products Laboratory, Forest Service, U.S. Department of Agriculture.

Pencil Point Data Sheets - Don Graf.

Federal Specifications.

CHAPTER XXV - PAINTING AND FINISHING WORK

217. Painting and Finishing of Wood.

The principal reason for coating woodwork is for the improvement and maintenance of its appearance. Immediate considerations in coating wood for appearance are:

(1) Paint and enamel are opaque and therefore conceal the grain and color of the wood, substituting a color, sheen, and texture of their own.

(2) Varnish, lacquer, oil, and wax are transparent, thus revealing the grain of a piece of wood more fully by displacing the air at its surface with a medium of much higher refractive index. In conjunction with stain the color is also altered. The sheen and the texture of the coating are substituted for those of the wood.

(3) Stain without varnish or lacquer changes the color of wood without greatly altering its sheen or texture.

Ultimate considerations in coating wood for appearance are:

(1) Unless protected by moisture-retardant coatings, wood which is exposed to the weather becomes dull gray in color. Smoothly planed surfaces become rough and cracked. Boards tend to cup, twist, and pull loose from their fastenings. Short boards tend to split. Snug joints become loosened. Straight, parallel lines are disarranged. Durable coatings, adequately maintained, prevent such weathering.

(2) Uncoated interior wood surfaces are porous enough to absorb liquids quickly, to stain and spot readily, and to hold dirt tenaciously. Nonporous coatings or coatings that tend to shed liquids, protect wood from discoloration and present a surface which may be easily cleaned.

Those parts of buildings that are customarily kept painted are not, as a rule, subject to much hazard of decay by wood-destroying fungi because they are well drained and dry rapidly. Ordinary paints and varnishes are not effective as preservatives against fungous decay.

Paint is chosen for exterior woodwork more often than any other coating. It is much more durable than varnish or other transparent coatings, and usually affords more effective protection a-

gainst weathering of the wood. Exterior enamel may be used in place of paint where a smoother, harder, and more wear-resistant coating is needed. Enameled surfaces may be washed at intervals to improve the appearance. It is best to use enamels only on surfaces that are accessible enough to be easily repainted more frequently than the major surfaces of the building. Porch railings, columns, and door and window frames can often be enameled to advantage.

218. Painting Characteristics of Woods.

The same painting procedure and the same kinds of paint are suitable for covering all native softwoods or conifers, and the native hardwoods that have relatively small vessels or pores. Hardwoods with relatively large vessels require a wood filler before being painted or varnished.

A. Spreading Rates on Softwoods or Conifers.

The spreading rate of paint is the area of surface covered by a unit volume of paint. On smoothly planed surfaces of softwoods, the spreading rate varies with the species only for the first or priming coat of paint applied on the new surface. The spreading rate of subsequent coats does not vary with the species.

Even for priming-coats, the species of wood has less effect on the spreading rate than the individuality of the painter or the kind and proportion of the ingredients in the paint. Some painters brush the paint out farther than others. The best painters apply the paint in fairly thick coats, covering roughly 600 square feet per gallon. Unskilled painters very often apply the coating too thinly and cover as much as 1,000 or 1,200 square feet per gallon. A few of the native softwoods tend to take 10 to 12 percent more priming-coat paint than the average, and a few tend to take as much less. By the time the second and third coats have been applied, the difference in paint consumed amounts to only 3 or 4 percent above or below the average. This value is probably within the limits of uniformity with which a good workman will paint at different times. The woods that tend to take more than the average amount of paint are, in general, the lightweight ones. Those that tend to take less paint are the heavy ones that have a high proportion of summer wood. Rough surfaces, such as shingles and the sawed side of bevel siding may consume twice the amount of priming-coat paint required for smoothly planed surfaces. Weathered wood, or surfaces on which repainting has been neglected for a long time, act similar to rough surfaced wood.

B. Drying of Paint on Softwoods.

The time required for a coating of paint to dry or harden, depends almost entirely upon the composition of the paint, the intensity of sunlight, and the temperature and relative humidity of the atmosphere. The drying is retarded if the wood is wet when it is painted. The moisture content should not exceed 20 percent. Priming coat paint may remain liquid for several days on wet redwood or southern cypress, especially if the paint contains little or no white lead or zinc sulphide pigment. Paint hardens as rapidly on air-dry redwood as on any

other wood. In the absence of sufficient sunlight, paint may take longer than usual to harden on air-dry cypress. Unless the drying takes place in strong sunlight and the boards are reasonably dry, the hardening of paints lacking white lead or zinc sulphide may be retarded on cypress boards that contain much more than the average amount of the oily extractive material which is characteristic of cypress.

C. Filling Porous Hardwoods before Painting.

Birch has pores large enough to take wood filler effectively when desired, but small enough, as a rule, to be painted satisfactorily without filling.

Hardwoods having small pores may be painted with ordinary house paints in exactly the same manner as softwoods. For hardwoods with large pores, the usual priming-coat paint should be replaced with a wood filler. This is a paste consisting of a pigment which is chiefly ground quartz, mixed with linseed oil and a paint drier.

A filler is necessary on woods having large pores because paint applied by a brush or a spray gun does not properly fill the pores. Without a filler, the pores not only appear as depressions after the painting has been finished, but also act as centers for disintegration of the coating.

D. Effect of the Nature of Wood on the Wearing Qualities of Paint.

During the first year or two after an exterior wood surface has been painted properly, the nature of the wood usually has very little effect on the behavior of the paint coating. Later on, when the coating has become embrittled with age, differences between woods become very important and largely determine the rapidity of the disintegration of the coating. Under normal conditions of exposure, paint coatings on wood deteriorate most rapidly where the greatest amount of sunshine falls. Deterioration proceeds in successive but overlapping stages as the following:

(a) The soiling stage. The coating gradually becomes dirty.

(b) The flatting stage. The coating loses its gloss.

(c) The chalking stage. Dirt may be thrown off more or less completely, but colors appear to fade.

(d) The fissure stage. Fissures are of two general types, depending upon the nature of the paint.

(1) Checking. The fissures are at first superficial, but later may penetrate entirely through the coating.

(2) Cracking. The fissures pass entirely through the coating when first observed. Sooner or later the coating at the edges of the cracks comes loose from the wood and curls outward. As a rule, cracking comes at a more advanced stage of paint embrittlement than checking.

(e) The disintegration stage. Behavior in the fissure stage determines the form in which disintegration takes place:

(1) Crumbling, which develops from checking, consists of the falling away of tiny fragments of coating which are cut off when the fissures become interwoven and penetrate entirely through the coating.

(2) Flaking, which develops from cracking and curling. The loosened edges of coating that curl outward finally fall off, after which the newly formed edges curl outward and the process continues. Flaking is usually a more rapid form of disintegration than crumbling.

From the time that cracking or disintegration begins, the nature of the wood dominates the further rate of progress of failure. On softwoods, cracking, crumbling, and flaking progress chiefly over the bands of summer wood. The wider the bands of summer wood intersected by the painted surface, the more rapidly disintegration proceeds and the more conspicuous the areas laid bare. Repainted coatings behave in much the same way as coatings applied to new wood except that the fragments of coating that fall off may be somewhat larger and may not begin to come off quite so soon.

The following wood properties or characteristics largely determine how long softwood boards will satisfactorily retain paint:

(a) Wood of light weight or low density holds paint longer than heavy wood because it contains less summer wood.

(b) Narrow-ringed wood holds coatings longer than wide-ringed wood because the bands of summer wood are narrower.

(c) Edge-grain surfaces hold coatings longer than flat-grain surfaces, because the bands of summer wood are narrower at the surface.

(d) Flat-grain boards may hold paint better on the bark side than on the pith side because there is a tendency for the edges of the bands of summer wood to loosen and curl outward on the pith side, thus dislodging the coating.

(e) High-grade lumber holds coatings better than low-grade lumber because knots and other defects hold paint poorly and because the low grades usually come from the center of the tree where the wood is likely to be wider ringed.

Coatings begin to fail to protect wood against weathering when deep fissures develop. The consequences of inadequate protection depend upon the characteristics of the wood. Edge-grain boards are less seriously affected than flat-grain boards of the same species. Woods that hold their shape well and do not develop conspicuous checks or cracks on weathering are less seriously affected by inadequacy of paint protection than are other woods.

E. Classification of Softwoods for Painting.

The classification of native softwoods by species with respect to their painting characteristics, is based upon the average behavior of commercial shipments of select grades of the different woods. The material observed was of a quality that might be used for house siding or millwork. Boards of any one species may vary widely in paint retention. In general, boards selected for the physical properties that favor paint durability will serve much more satisfactorily than the average run of the species rated in the classification.

Classification, by Groups, of Softwoods for Painting

Group 1 - Woods that hold paint longest and suffer least when protection against weathering becomes inadequate. This group includes: Alaska cedar, Incense cedar, Northern white cedar, Port Orford cedar Southern white cedar, Western red cedar, Southern cypress, and Redwood.

Group 2 - Woods that hold white-lead paint as long as those of group 1 but do not hold mixed-pigment paints quite so long and suffer more than those of group 1 if protection becomes inadequate. This group includes: Northern white pine, Western white pine, and Sugar pine.

Group 3 - Woods that do not hold either white-lead paint or mixed-pigment paints so long as woods of group 1 and suffer more than woods of group 1 if protection becomes inadequate. This group includes: Comm. white fir, Eastern hemlock, Western hemlock, Ponderosa pine, Lodgepole pine, Eastern spruce, Engelmann spruce, Sitka spruce.

Group 4 - Woods that do not hold paint coatings so long as woods of group 3. This group includes: Douglas fir, Western larch, Norway pine, S. yellow pine, and Tamarack.

F. Effect of Extractives in Wood on Paint Behavior.

In general, the extractives in wood have much less effect on paint behavior than has been commonly supposed. They are far less important than the width of the bands of summer wood.

Distinction must be made between piny resins, which are characteristic of pines but occur also in other softwoods, and other extractives.

Piny resins consist of a solid rosin and a volatile liquid such as turpentine. They affect paint unfavorably by exuding through coat-

ings, leaving unsightly encrustations. Exudation is minimized by thorough seasoning of the lumber to drive out the turpentine, rendering the resin less mobile. Much longer seasoning is necessary to remove turpentine than to remove moisture. The piny resins may also be responsible for the fact that paints containing zinc oxide fail somewhat more rapidly on the pines than they do on other softwoods having bands of summer wood of similar width.

Other extractives in wood may have a favorable effect on the durability of paint. There is evidence that such is the fact with extractives in redwood and southern cypress, although colored extractives in redwood and red cedar which are soluble in water may exude through coatings if the wood beneath the coatings becomes very wet. These discolorations do not occur under normal dry conditions.

G. Effect of Impregnated Preservatives on Painting.

Wood which has been treated with the water-soluble and other somewhat colorless preservatives in common use, can be painted satisfactorily. The life of the coating may in some instances be slightly less than it would have been on the untreated wood. The loss in durability is not enough to offer any practical objection to the use of treated wood for purposes where preservation against decay is necessary, and where a good appearance is desirable. Coal-tar creosote or other dark oily preservatives tend to stain through paint. No entirely satisfactory method of painting over them is known. Fairly good results can be obtained with 1 or 2 coats of exterior aluminum paint.

219. Choice of Paints for Exterior Woodwork.

House paints of the best quality are recommended for nearly all exterior painting needs. Inferior paints made to sell at materially lower prices must be applied in a greater amount to accomplish the same result. They may not last so long, and are generally less reliable. It is usually cheaper to use a high-grade paint in the minimum number of coats even when a low initial painting cost is the chief consideration. The labor for a paint job usually costs several times as much as the paint. Paints of a good quality and made with iron oxide pigments are economical for both low initial cost and great durability, whenever the colors are acceptable. Two coats of exterior aluminum paint make an exceedingly durable and highly protective covering when a metallic appearance is not considered undesirable. Old-fashioned whitewash or modern types of exterior water or water-emulsion paints are safer to use than linseed oil paints of an inferior quality. The water paints give their best service on rough surfaces rather than on smoothly planed wood. They are often used where frequent repainting is desirable and where protection against weathering is not necessary.

For residences or buildings of architectural pretension, white or light-colored paints are most popular for the major painted surfaces. It is supplemented if desired, by deeply colored paints on the minor surfaces. When deep colors are appropriately dominant, it is often better, and much more economical to use rough wood surfaces such as shingles or sawed siding and to apply exterior stains rather

than gloss paints. Colors for exterior surfaces should be selected with reference to the particular setting of the building, as well as to the type of finish of the wall or exposed surfaces.

A. Paste and Prepared Paints.

Paste paints contain a greater proportion of pigment than prepared paints, and must be thinned with more linseed oil and turpentine to make them ready for application. If paste paints are manipulated by a skillful painter in accordance with the particular conditions prevailing on the job, a close adherence to the traditional technique of the paint craft is possible. In congested urban locations or in parts of the South where mildew is troublesome, it is advantageous to mix even the finish-coat paint with less linseed oil than is present in prepared paint.

Unskilled or unscrupulous painters can make far more serious blunders in manipulating paste paint than they can make with prepared paint. The manufacturer of prepared paint can make sure that a large proportion of the linseed oil used in the paint is of the type most compatible with the particular kinds of pigments he has used. Another advantage of prepared paints is that they are commonly sold in a much greater variety of colors than paste paints, so that tinting by the painter is unnecessary. They are easier for the ordinary home owner to use for general household painting purposes.

B. Composition of Paint.

The quality of a house paint depends upon the quality of the liquids, the quality of the pigments, and the proportions of pigments and liquids of which it is made.

(a) Quality of the Liquids.

Linseed oil is the most widely accepted liquid ingredient for exterior paints for wood. It is available in many degrees of refinement for different purposes. A proper choice of the kind of linseed oil most suitable for the pigments used is essential for making high-grade paint. As a rule, the purchaser of paint must rely upon the manufacturer's judgment in selecting the kind of oil.

Substitution of other drying oils for a part of the linseed oil is not necessarily detrimental to the quality of the paint. Most of the liquid in high-grade paste or prepared paints consists of from 80 to 100 percent by weight of linseed oil or linseed oil and other drying oils. Raw or boiled linseed oil of good quality should be used to thin paints for application.

Varnish is rarely a desirable ingredient of the liquid of a good house paint. Cheap varnish is often used in inferior paints because large proportions of inexpensive volatile thinners can then be incorporated. Good exterior varnish or heat-treated linseed oil or tung oil is necessary in the manufacture of exterior enamels or exterior floor paints which must stand mechanical wear as well as weathering. As much as 50 percent by weight of the liquid of such

enamels or floor paints of good quality may be a volatile thinner. Synthetic drying oils are now manufactured for paint oils. They make paints that dry faster than linseed-oil paints, but they have not been in use long enough for their merits to be well established.

The volatile thinner in most paints is mineral spirits, which is a petroleum product. Turpentine is commonly recommended for use in thinning paint. Good paint should not contain more than 1 or 2 percent by weight of water in the liquid.

(b) Quality of the Pigments.

Differences in the behavior of linseed-oil paints during the successive stages in deterioration with age are determined largely by the nature of the pigments. No kind of paint now known is superior in all stages of deterioration. Improvement in one stage is usually effected at some sacrifice in other stages. For that reason the user's judgment about the relative importance of the different stages, and particularly about the stage at which he expects to repaint, determines what kind of paint he can use advantageously. For intelligent paint maintenance, the user should know the pigment composition of the paint and its bearing upon behavior during deterioration.

The opaque white pigments predominate in good white paints. Tinted paints, which include the majority of colored house paints, are essentially white paints which contain minor proportions of colored pigments. The good white paints used as bases for tinting may be grouped for convenience as follows:

(1) Pure white lead paint.

The pigment of pure white-lead paint is entirely basic carbonate white lead. During the soiling and flatting stages of its life, white-lead paint may become dirtier than mixed-pigment paints. This is especially true in congested urban locations and in deeply shaded places or when the paint is applied during late fall, winter, or early spring. Chalking of white-lead paint and fading of tinted paint usually sets in fairly early. After this happens, the dirt is thrown off promptly and evenly, leaving a clean surface which may contrast strongly with deeply shaded parts of the building that are still dirty and not yet faded. Checking begins comparatively early, and is usually inconspicuous. It gradually works deeply into the coating, and for that reason cracking and flaking rarely occur. The outstanding merit of white-lead paint is the longer interval between checking and the beginning of crumbling and the slow progress of crumbling in the stage of disintegration. Even badly neglected white-lead-painted surfaces can usually be covered fairly smoothly and durably with new paint unless large weather checks have developed in the wood. Initial painting with white-lead paint provides a very satisfactory foundation for subsequent painting with mixed-pigment paints. It is not advisable to apply pure white-lead paint over mixed-pigment paints because checking may then assume the conspicuous form known as "alligatoring".

(2) Lead and Zinc Mixed Pigment Paints.

A part of the basic carbonate white lead in good mixed-pigment paints of the lead-and-zinc type is replaced by zinc oxide. Other parts may or may not be replaced by inexpensive transparent pigments such as magnesium silicate, silica, barium sulphate, clay, or calcium carbonate. Basic carbonate white lead and basic sulphate white lead are commonly considered interchangeable in such paints. Either one, or any mixture of the two may be used for the white-lead content of the pigment. Incorporation of the zinc oxide reduces the chances of excessive soiling of the coating and retards both chalking and checking. The appearance of the surface during the soiling, flatting, and chalking stages may therefore be somewhat better than that of pure white-lead paint. This is more pronounced if the paint is tinted, but the coating may remain dirty for a longer time. Ultimate disintegration of lead and zinc paints usually takes place by cracking, curling and flaking. If the zinc oxide content is high, a long neglect of repainting after flaking starts may leave a surface that cannot be smoothly and durably repainted without a complete removal of the old coating. Federal Specification TT-P-36 for lead-and-zinc paint requires that the content of white lead shall be not less than 60 percent by weight, and that the sum of the white lead and zinc oxide shall be not less than 90 percent of the total pigment. Transparent and colored pigments together must therefore be limited to 10 percent of the total pigment. Some authorities who regard this as a satisfactory specification for white paint, think that for tinted paints the minimum sum of white lead and zinc oxide should be 85 percent of the total pigment. In parts of the South where the relative humidity is always high, chalking and fading of paint are stimulated, while cracking and flaking are retarded and paints are subject to the growth of mildew. For such a climate it is advantageous to increase the content of zinc oxide to as much as 50 percent of the total pigment.

(3) Opaque White Mixed-Pigment Paints.

Mixed-pigment paints which contain very opaque white pigments may be considered as lead-and-zinc paints, in which part or all of the white lead is replaced by titanium or zinc sulphide or a combination of the two. Good paints of this type are characterized by unusual freedom from dirt in the soiling stage and by prompt shedding of dirt in the chalking stage. When white lead is replaced entirely by one of the titanium pigments, fissure development may be greatly retarded and checking may be entirely prevented. If repainting is postponed too long, checking and flaking will develop as in the mixed pigment paints already discussed.

The most popular titanium pigment for exterior paints is a mixture of 25% of titanium dioxide and 75% of barium sulphate by weight. Some paint manufacturers prefer to use pure titanium dioxide. In this case it is good practice to mix one part by weight of titanium dioxide with about 1-3/4 parts of magnesium silicate, silica, or calcium carbonate to obtain a titanium pigment that can properly replace 2-3/4 parts of white lead in good lead-and-zinc paints. The most important zinc sulphide pigment is lithopone, which contains about 30% of zinc sulphide and 70% of barium sulphate. Pure zinc sulphide is now used in a few brands of house paint.

(4) Colored Pigments.

Dull red, brown and yellow pigment paints are made most economically with either natural earth or manufactured iron oxide pigments. For good retention of color and for maximum durability, the iron oxide content of the pigment may well be 80% or more by weight, and should not be less than 30%. Bright reds require organic lake pigments that are more expensive but less durable than the iron oxide reds. Bright yellows and oranges are made with chrome yellows which are lead chromates and basic lead chromates. These are fully as expensive as white pigments, but are more durable.

Greens are made with chrome green, which is a mixture of chrome yellow and Prussian or Chinese blue (iron ferro-cyanide). Durable blacks are made with carbon pigments such as lamp black. Asphalt paints are cheaper, but are less durable blacks when exposed to the weather. Colored pigment paints often retain their color and protective power better if they contain some zinc oxide or white lead. If they do not, it is advisable to apply them over priming coats of white lead or aluminum paint.

(c) Proportions of Pigments and Liquids.

Pigments impart durability as well as color and capacity to paint. For that reason there is an optimum proportion of pigments and linseed oil in good paint. Although the optimum proportions have not been accurately determined to the satisfaction of all authorities, it is good practice to keep the pigment volume, which is the percentage of volume of the total pigments to the total non-volatile ingredients, within the range of 25 to 32% in the finish-coat paint.

Paints may become unnecessarily dirty at the lower end of this range or below it. They may rapidly lose gloss and soon begin to chalk or fade at the upper end of the range or above it. Prepared paints and paste paints thinned for application as finish coats, should have a pigment volume within this range, preferably near the upper part of it. Inferior paints, unless they contain a very large proportion of transparent pigments, are usually deficient in pigment volume. Linseed oil can be readily added if it should be desirable but it is seldom practicable to remove the excess oil from prepared paints.

After the correct ratio of pigments and linseed oil has been established, some volatile thinner is usually necessary to obtain a good brushing consistency and convenient application at the proper spreading rate. Paints that require unusually large amounts of thinner to establish a good brushing consistency, have "false body", and may justly be regarded as of questionable quality. The pigment volume in paint is not consistently indicated in the manufacturer's statement of composition, which gives the proportions of ingredients by weight. It can be easily calculated if the specific gravity of each of the ingredients is known.

C. Exterior Stains.

Exterior wood stains are essentially paints, which have been greatly diluted with linseed oil, volatile thinners, or creosote. Stains are cheaper than paints, but they do not protect smooth wood surfaces against weathering. They are most suitable for rough surfaces such as shingles, or siding which is placed with the sawed side out. Good stain should contain only pure, finely divided opaque pigments and must be free from transparent pigments. The pure iron oxide, chrome, and carbon pigments are very satisfactory.

The liquid part of the stain should be at least 1/3 linseed oil by volume, although some authorities recommend 2/3. Particular merits are claimed for stains made with the pigments ground in very highly bodied linseed oil. The pigments are more highly dispersed in such liquids, and become more deeply embedded in rough wood surfaces. Houses which are covered with stained shingles or siding, and have smoothly planed and painted wood trim, often have the trim painted twice for each time that the side walls are stained.

D. Varnishes.

Transparent varnishes are rarely practicable on exterior surfaces which are fully exposed to the weather, except on small, easily accessible surfaces such as doors. This is true because even the best varnishes are far less durable than paints. When transparent finishes are used, it is essentiel that the varnish be promptly renewed when necessary to prevent the wood from turning permanently gray.

220. Application of Paint.

Wood should not be painted when it is wet, but the moisture content is of minor importance as long as no free water is present. Wood which is painted at 16% to 20% moisture content holds paint slightly longer than wood which is painted at 10% moisture content. Paint dries very slowly at low temperatures, and painting should not be done at times when the temperature is likely to fall below 40° F. The application of paint should cease several hours before sunset, if there is a possibility of dew or frost at night. If necessary, successive coats of paint can be applied within 24 hours of each other in clear warm weather, but it is better practice to allow at least two or three days between coats. It is generally inadvisable to allow more than one or two weeks to elapse between successive coats.

The surface of the wood must be clean before the priming coat is put on. All knots and resin should be coated with shellac to prevent discoloration of the paint. The painting of wall surfaces should usually start at the top and should progress downward.

Blistering and peeling of paint on new houses is usually caused by faulty methods of drying the interior plastering, which drive the moisture into the sheathing and siding. If there is a doubt about the moisture content within the wall it is best to apply only the priming coat and to defer the remaining coats until the walls are

thoroughly dry. The priming coat will not blister, but it furnishes only a partial protection against weathering. For this reason the balance of the painting should be completed as soon as it is safe to do so.

Paint may be applied by a brush or a spray gun with equally serviceable results on new wood surfaces, or on painted surfaces on which the old coating has not yet become deeply cracked. Sprayed paint may not prove so durable as brushed paint on old coatings that have passed well into the fissure or flaking stage of paint deterioration.

The conventional method of painting new wood surfaces requires the application of three coats of paint. The three coats are usually of the same kind of paint except for differences in proportions of pigments, linseed oil and turpentine. The current trend is towards the use of special paints for priming or first coats. Aluminum paint is recommended as a priming coat by the Forest Products Laboratory in their circular of April, 1936, entitled "Effectiveness of Paints As Protective Coatings for Wood".

Much new wood is now covered with only two coats of paint, but this practice frequently leads to unsatisfactory results. Two-coat painting is practicable when it is properly done, but it requires more skillful workmanship than three coat painting.

221. Mixing of Paints.

It is a well-established practice in three-coat painting of new wood surfaces for the priming-coat to have a pigment volume between 20% and 25%, the second-coat between 35% and 40%, and the finish-coat between 25% and 32%. The high pigment volume in the second coat requires the use of paste paint. When prepared paint is used, it is generally necessary to have the same pigment volume in the second and finish coats, but the second coat should never have a lower pigment volume than the finish coat. In two-coat painting of new wood surfaces both coats may have a pigment volume between 25% and 32%. They should be applied thicker than is customary in three-coat painting.

The following table presents suitable directions for thinning paste paints in accordance with the foregoing practices if the approximate proportion of total pigment in the paste paint is known. The painter has little control over the pigment volume in prepared paint. In general, not more than 1 quart of linseed oil and 1 pint of turpentine should be added to a gallon of prepared paint for the priming coat. The second coat should be thinned with 1 pint of turpentine and no linseed oil. As a rule, no addition is made to prepared paint for the finish coat.

Approximate amounts of linseed oil and turpentine to be added to 1 gallon of paste paint for painting new wood surfaces

Reduction and Spreading Rate	For 3-coat initial painting			For 2-coat initial painting	
	First coat	Second coat	Third coat	First coat	Second coat
For soft paste* white-lead paints containing more than 50% pigment by volume:					
Raw linseed oil** ....quarts	6	2	4	4	4
Turpentine "	1-1/2	1-2/3	0	1	0
Spreading rate*** sq. ft. per gal.	575	600	600	450	500
For paste* paints containing 40 to 50% pigment by volume:					
Raw linseed oil** ....quarts	5	1-1/2	3	3	3
Turpentine "	1	1	0	1	0
Spreading rate*** sq. ft. per gal.	575	600	600	450	500
For paste* paints containing 40% pigment by volume:					
Raw linseed oil** quarts.....	3-1/2	1	2	-	-
Turpentine...qts.	1	1	1/2	-	-
Spreading rate*** sq. ft. per gal.	550	575	575	-	-

*About 1/3 pint of liquid paint drier should be added in each of the above mixtures if the paste paint contains no drier.

**Boiled linseed oil should be used in place of raw linseed oil only if the manufacturer indicates that it is satisfactory.

***If additional thinning is necessary to give a good brushing consistency, thin further with turpentine and not with linseed oil, and apply the paint at a correspondingly lower spreading rate. For congested urban districts where paint becomes very dirty or where mildew is troublesome, the amount of linseed oil added to finish coats may be reduced by about 1 pint and the amount of turpentine increased by about 3/4 pint.

Changes in priming-coat reductions according to the nature of the wood being painted are often recommended in the mistaken belief that the differences in painting characteristics of wood can be offset in that way. The priming-coat mixtures given in the foregoing table are suitable for all native softwoods. The common suggestion of mixing priming coats with more than the usual proportion of turpentine is definitely bad practice for resinous woods such as southern yellow pine.

The durability of paint on woods of groups 3 and 4 of the classification shown on Page 401 can often be materially increased by using special priming paints. When it is used as a priming coat for mixed-pigment paints high in zinc oxide, pure white-lead paint may be considered a special priming paint for this purpose. The experience of the Forest Products Laboratory indicates that the most effective special priming paint for woods of groups 3 and 4 is exterior aluminum paint. Aluminum priming paint is usually made with 2 pounds of dry aluminum powder of the standard varnish grade, or 2 pounds of commercial paste aluminum mixed in 1 gallon of long-oil spar varnish made specifically for that purpose. The right kind of varnish must be used. The aluminum primer hides the surface of the wood completely if it is properly applied. Aluminum priming paint, in common with other colored primers, makes checking more prominent in these paints in which it occurs. If the aluminum primer is suitable, it does not hasten the development of checking nor alter the pattern in which it occurs.

222. Repainting.

The fundamental factor in good paint maintenance is to repaint at the right time. Neglect of repainting results in damage that cannot be satisfactorily repaired by mere application of paint. Warped and checked boards are not restored by paint, and a badly broken old coating cannot be covered smoothly.

It sometimes happens that a relatively small number of boards on a house lose their paint much sooner and more conspicuously than the rest of the boards. In such cases, the average life of subsequent coatings can often be increased by replacing these boards with new ones chosen for good painting characteristics.

Those who are willing to repaint often to maintain the best possible appearance may do their repainting at some time during the chalking state of deterioration. They should either apply two coats fairly thinly or apply one substantial coat of paint after the dirt has been removed from the old paint.

Those who wish to repaint as infrequently as is consistent with good maintenance usually wait for the fissure stage or the early part of the disintegration stage before repainting. Two coats are then advisable, and are usually necessary if crumbling or flaking has begun. Any loosened parts of the old coating should be removed with a putty knife, wire brush, or with sandpaper, and conspicuous spots of bare wood should be touched up with priming-coat paint. Two full coats of paint should then be applied.

Approximate amounts of linseed oil and turpentine to be added to 1 gallon of paste paint for repainting during the fissure stage or the very early disintegration stage of the old coating.

Reduction and spreading rate	First coat	Second coat
For soft paste* white-lead paint and paste paints containing more than 50% pigment by volume:		
Raw linseed oil**.....quarts	2-3/4	4
Turpentine..... "	2-1/3	0
Spreading rate*** sq. ft. per gal.	600	600
For paste* paints containing 40% to 50% pigment by volume:		
Raw linseed oil**.....quarts	1-2/3	3
Turpentine..... "	2	0
Spreading rate*** sq. ft. per gal.	600	600
For paste* paints containing less than 40% pigment by volume:		
Raw linseed oil**.....quarts	1	2
Turpentine..... "	2	1/2
Spreading rate*** sq. ft. per gal.	575	575

*About 1/3 pint of liquid paint drier should be added in each of the above mixtures if the paste paint contains no drier.
**Boiled linseed oil should be used in place of raw linseed oil only if the manufacturer indicates that it is satisfactory.
***If additional thinning is necessary to give a good brushing consistency, thin further with turpentine and not with linseed oil, and apply the paint at a correspondingly lower spreading rate. For congested urban districts where paint becomes very dirty or where mildew is troublesome, the amount of linseed oil added to finish coats may be reduced by about 1 pint and the amount of turpentine increased by about 3/4 pint.

If repainting is neglected until long after flaking sets in, the surface may present a difficult and uncertain problem unless the old paint was one that stands neglect well. The safest procedure may be to burn off the old coating completely and repaint with three coats, as for new wood.

Patent paint removers may be used to remove old paints and varnish finishes. "Wonderpaste" has been recommended by the Forest Products Laboratory as a product serving this purpose satisfactorily. Paint removers should be used according to the instructions furnished by the manufacturers.

For ease of maintenance of paint over a long period it is advantageous to adhere to one type of paint, at least for all paintings after the first one. Changing the type of paint at each time of painting, builds up a coating of varying composition with the danger that unpredictable vagaries in behavior may be encountered.

223. Blistering of Coatings.

Quite often the paint coatings on wood buildings do not undergo the normal course of deterioration already described but fail in an unreasonably short time from other causes. These may be blistering followed by peeling or scaling of the coating, or discoloration caused by exudation of water-soluble dyes contained in the wood, or by blue stain fungi growing in sapwood. Such abnormal paint behavior is invariably caused by moisture gaining access to the backs of the painted boards. The quality of the paint, the workmanship during its application, and the nature of the wood are not directly responsible for such abnormal behavior, because under such circumstances all paints fail, and trouble may be expected on any kind of wood.

There is only one remedy for abnormal paint behavior of this kind. That remedy is the location of the source of the moisture and the improvement of conditions to eliminate it.

Moisture may gain entrance to the side walls of buildings in several ways. One way is by seepage of rain water or melting snow through joints. Another is by condensation of warm moisture-laden air that originates within the building, circulates through hollow side walls, and is chilled when it meets the surfaces of sheathing or siding during cold weather.

The following points in frame building have frequently been found to be sources of seepage moisture: Junctions between the siding and corner boards, window and door casing, and chimney masonry; junctions between side walls and porch roofs; junctions between porch columns and plinth blocks; and leaking roofs, eave troughs, and down spouts.

The following conditions have often caused condensation of moisture within painted side walls; Hastening of the drying of plaster by heating without adequate ventilation; enclosing damp, stagnant air spaces under porches or parts of structures extending beyond the basement excavation; lack of ventilation in unused attics; failure to obtain a watertight basement; plumbing leaks; and artificial humidification or activities within the building that give off much moisture during cold weather.

224. Back priming and Mill priming.

Concealed surfaces are sometimes painted to retard changes in the moisture content of the wood. More than one coat is rarely used, and the same priming-coat paint is applied that is used on the exposed surfaces. Siding, shingles, and millwork are the principal items of building lumber that are back primed in this way.

The practice of priming lumber and woodwork at the mill is increasing. One object of mill priming is to give protection against moisture during shipment and storage, and during erection before the final finishing is possible. Mill priming should include back priming where practicable, because boards which are coated on one side are more likely to warp due to changes in moisture content than uncoated boards or boards coated equally on all sides.

No coating has been found that completely prevents changes in the moisture content of wood. The best that can be done is to retard the rate of change. Good coatings furnish adequate protection against rapidly changing atmospheric conditions or against alternate rain and sunshine, but they are relatively ineffective against prolonged exposure to extreme conditions. Neither do they prevent seasonal fluctuations in the moisture content of interior woodwork.

The degree of protection attainable with a priming coat alone is usually limited. At least two coats and often three, are necessary to build up an adequate barrier against moisture. Mill priming, therefore, affords only a very moderate degree of protection against change in moisture content before installation. After woodwork has been installed, the benefit derived from back priming is probably limited.

225. Uncoated Exterior Woodwork.

Architectural design sometimes specifies that wood have a weather-beaten appearance. The best way to attain this is to let the wood weather naturally, especially since uncoated exterior woodwork is not necessarily lacking in durability. For weathered construction it is advisable to choose woods that weather with a minimum of cupping twisting, and conspicuous checking. Edgegrain boards weather better than flat-grain boards, and thick boards weather better than thin ones It is best to exclude boards containing pith and to place flatgrain boards with the bark side out. Fastenings for weathered construction should be secured firmly with noncorrosive metals. Joints should be designed to prevent, as far as possible, the retention of moisture.

226. Interior Finishing.

Interior finishing usually requires much less adequate protection against moisture than exterior woodwork, but more exacting standards of appearance and a greater variety of effects are expected. Good interior finishes should last much longer than exterior paint coatings, but no interior finish should ever be used out of doors.

A. Opaque Finishes.

Interior surfaces may be painted with the materials and by following the procedures recommended for exterior surfaces. Smoother surfaces, better color, and a more lasting sheen are usually demanded for interior woodwork, and therefore, enamels rather than paints are employed. These finishes differ from paints in that linseed oil is replaced partly or entirely by bodied oils or by varnishes. This replacement makes a coating that does not show brush marks and presents a harder surface with the desired degree of gloss. Enamels may also be made of nitrocellulose lacquers or synthetic resins, mixed with oils that dry much more rapidly than oleo-resinous enamels. Unless they are made with expensive pigments of extraordinary opacity, such as titanium dioxide or zinc sulphide, enamels are less opaque than paints of the same color because they cannot be made with so large a proportion of pigment.

Before the wood is enameled the surface must be made extremely smooth. Imperfections, such as planer marks, hammer marks, and raised grain, are accentuated by enamel finish. Raised grain is especially troublesome on flat-grain surfaces of the heavier softwoods. This is because the hard bands of summer wood are sometimes crushed into the soft spring wood during the planing process and are later pushed up again when the moisture content changes. It is helpful to sponge softwoods with water, allow them to dry thoroughly, and then sandpaper them lightly with sharp sandpaper before enameling. Woodwork in new buildings should be allowed adequate time to come to its equilibrium moisture content before it is finished.

Hardwoods having large pores must be filled with wood filler before the priming coat is applied. For all woods, the priming coat may be white-lead paint mixed according to the directions for exterior priming-coat paint, or special priming paints made for that purpose. Knots in ponderosa pine, southern yellow pine, or the white pines, should be shellacked after the priming coat is dry. A full coat of shellac is sometimes necessary over ponderosa pine and the white pines to prevent discoloration of light-colored enamels by colored matter apparently present in the resin of the heartwood of these species. One or two coats of enamel undercoat are next applied. This should completely hide the wood and should present a surface that can easily be sandpapered smooth. For best results the surface should be sandpapered before applying the finishing enamel, but this operation is sometimes omitted. After the finishing enamel has been applied it may be left with its natural gloss or rubbed to a dull finish.

B. Transparent Finishes.

There are many good ways of applying transparent finishes to either hardwoods or softwoods. Most finishing consists of some combination of the following fundamental operations: Filling, staining, sealing, surface coating, rubbing, and polishing. Before finishing, planer marks and other blemishes of the wood surface that would be accentuated by the finish must be removed.

Both softwoods and hardwoods are often finished without staining, especially if the wood has a pleasing and characteristic color. Stain often provides much more than color alone, because it is absorbed unequally by different parts of the wood and therefore accentuates the natural variations in grain. Such emphasis of the grain usually is desirable in hardwoods, and the best stains for the purpose are dyes dissolved either in water or in oil. The water stains give the most pleasing results but raise the grain of the wood and require an extra sanding operation after the stain is dry. "Non-grain-raising" stains that often approach the water stains in clearness and uniformity of color are now available. Stains color the spring wood more strongly than the summer wood in softwoods, reversing the natural gradation in color in a manner that is often garish. Pigment-oil stains, which are essentially thin paints, are less subject to this objection than are other stains and are therefore more suitable for softwoods.

Hardwoods having large pores must be filled before a smooth varnish or lacquer coating can be applied. Filling is optional if a smooth coating is not desired. The filler may be transparent and without effect on the color of the finish or it may be colored to contrast with the surrounding wood. Colored filler is usually darker than the rest of the wood.

Sealer is used to prevent the absorption of subsequent surface coatings and to prevent the bleeding of some stains and fillers into surface coatings. Shellac is the oldest type of sealer. Varnish can be used as a sealer but is not so effective as shellac.

Surface coatings may be of wax, shellac, varnish, or nitrocellulose lacquer. Wax provides a characteristic sheen without forming a coating of sensible thickness and without greatly enhancing the natural luster of the wood. Coatings of a more resinous nature, especially shellac and varnish, accentuate the natural luster of some hardwoods and seem to permit the observer to look down into the wood to a certain extent. Shellac applied by the laborious process of French polishing probably achieves this impression of depth most fully, but the coating is easily marred by water and is expensive. Rubbing varnishes made with resins of high refractive index for light are nearly as effective as shellac. Lacquers have the advantage of drying rapidly and forming a hard surface but require more applications than varnish to build a lustrous coating.

Varnish and lacquer usually dry with a highly glossy surface. To reduce the gloss the surfaces may be rubbed with pumice stone and water or polishing oil. Waterproof sandpaper and water may be used instead of pumice stone. The final sheen varies with the fineness of the powdered pumice stone. Coarse powders make a dull surface and fine powders a bright sheen. The final rubbing is done with rottenstone and oil to give a very smooth surface with a high polish. Varnish and lacquer can be made to dry with a dull finish, but the result is not quite the same as that produced by rubbing.

C. Finishes for Floors.

Finishes for wood floors are subject to severe mechanical wear and consequently deteriorate more rapidly than finishes on most other classes of woodwork. Floor finishes must, therefore, be renewed frequently. Discussions of floor finishes usually place undue emphasis upon the kind or quality of material used and pay far too little attention to the maintenance. Any of the common types of floor finishes will keep wood floors in excellent condition if properly maintained, but no finish will do so if it is neglected. The essential problem is to adapt a systematic program of maintenance to the requirements of the finishing material chosen and of the degree of wear to which the floor is subjected.

The opaque and transparent interior finishes already described are applicable to floor finishing provided that they are made with the careful balance between toughness and hardness which is necessary to make them resistant to mechanical wear. The essential point in maintaining any floor finish that includes a surface coating, is to

recoat before the old coating has actually worn down to the wood in conspicuous spots. Good floor paints or varnishes require less frequent renewal than wax finishes under similar conditions of wear. Each renewal, however, is more expensive in material and labor and keeps the floor from being used for a longer time than finishes that do not include substantial surface coating. Coatings of any kind often prove unduly expensive and inconvenient for floors which are subject to heavy wear.

Such floors are often finished with floor oils that are absorbed by the wood and do not form substantial coatings. They furnish less adequate protection against moisture and dirt than coatings, but are cheaper and can be applied with less labor and inconvenience. Most floor oils darken the wood appreciably and do not present so fine an appearance as well-maintained coatings. A new method is coming into use that keeps oiled floors bright and clean by buffing them with steel wool after oiling, and at suitable intervals.

Floor waxes which are applied either directly to wood or over a sealer do not form substantial coatings. They are usually superior to floor oils in appearance, although they must be renewed even more frequently. Floor waxes of the emulsion type are very quickly and easily applied and are relatively inexpensive.

227. Painting Metal Surfaces.

Steel structures for Forest Service use should be painted with three coats of paint as follows:

Shop coat - red lead paint.
First field coat - red lead paint with a tint of lamp black.
Second field coat - aluminum paint. This paint should be used only over the first field coat of red lead.

A. Paints.

(a) Red lead paint.

Red lead paint should consist of red lead, linseed oil, turpentine, and drier, mixed in the following proportions:

Dry red lead	- F.S.-TT-R-191 -	20 pounds
Raw linseed oil	- F.S.-JJJ-O-336 -	5 pints
Turpentine	- F.S. - LLL-T-791a -	1/2 pint
Liquid drier	- F.S.-TT-D-651 -	1/2 pint

The resulting paint, when brushed on a smooth steel surface should dry hard and elastic without running, streaking, or sagging.

(b) Aluminum paint.

Aluminum paint should have the following composition:

Aluminum powder - - - - -	2.0 pounds
Spar varnish - - - - - -	1.0 gallon

If the paint is mixed in the above proportions it will contain approximately 21% pigment and 79% liquid. Ready mixed aluminum paint should not be used.

(1) Aluminum powder.

The powder should be made by the best commercial methods from metallic aluminum having a minimum aluminum content of 99%. On analysis, a sample should show not more than 1% by weight of iron, silicon, and copper after deducting the acetone soluble portion. The powder should conform to the following composition limits:

Acetone extract (2 hours) maximum - -	3.0 percent
Lead and zinc maximum - - - - - - - -	0.0 "
Copper maximum - - - - - - - - - -	0.2 "

The aluminum should be powder in the form of flakes, and possess the property of "leafing" when suspended in varnish. The fineness should be such that it will pass through a standard 100 mesh screen. This test should be determined by wetting a sample with alcohol and passing it through the screen. The aluminum powder should contain no powdered mica or other adulterants.

(2) Spar Varnish.

Varnish should meet Federal Specification #18b, for water-resisting varnish. The varnish should show satisfactory spreading qualities when thoroughly mixed with the aluminum powder in the proportion of 2 pounds per gallon. It should not run or sag when applied to a smooth vertical surface. The paint should set to touch in not less than 2 hours nor more than 6 hours and should dry hard and tough in not more than 24 hours.

B. Mixing.

It is recommended that both red lead paint and aluminum paint be mixed on the job, and only enough for one day's use should be mixed at one time. The weight amount of powder should be placed in a suitable container and the measured volume of varnish should be poured over the aluminum powder and should be thoroughly mixed by stirring with a paddle. The paint should be occasionally stirred during use.

C. Application.

Paint should be applied only when the air temperature is at or above 40° F. It must not be applied on damp surfaces or upon metal containing frost, nor when the air is misty, or otherwise unsatisfac-

tory for work. The finish strokes should generally be made in the same direction when aluminum paint is applied by brushing.

All metal surfaces must be clean and dry and free from rust, dirt, grease, scale or blisters before paint is applied.

Before repainting, the entire structure should be well brushed with a wire brush or well cleaned with a sand blast. All scale or blister spots must be hand scraped. All bare places should be given one priming coat of red lead paint. If the surface is in good condition except for spots, spot priming will be sufficient. If the surface is in poor condition, a priming coat should be applied to the entire surface.

Each coat should be allowed to dry thoroughly before the succeeding coat is applied. As the aluminum paint provides an air-tight seal, it is important that the red lead primer be thoroughly dry before applying the aluminum paint. The red lead paint dries slowly and about one week is recommended for allowing the priming coat to dry.

228. Painting Plaster, Brick and Cement Surfaces.

Surfaces of plaster, concrete and brick should be thoroughly cleaned of dust and loose dirt. A plaster surface should always be given a first coat of sizing. The sizing is usually cheap shellac or a specially prepared glue. Orange shellac can be cut by the addition of denatured alcohol to produce quick-drying sizing. Substitutes for shellac are available, which usually cut the cost about in half but they are generally not as satisfactory.

New brick or concrete surfaces should first be brushed with a solution of 3 pounds of zinc sulphide to one gallon of water. This has the effect of artificially aging the surfaces, and preventing the alkaline on the cement from discoloring the paint. A coating of shellac or varnish should be applied.

White-wash is sometimes used as a cheap coating for masonry work. If it is appropriate for the work it should be mixed and applied according to the Federal Specification for "Lighthouses".

References:

Wood Handbook - Forest Products Laboratory.
Federal Specifications.

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